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ABSTRACT

Presented from different perspectives, the five papers in this collection discuss three developments in education--the creation of educational environments that foster students' thinking, the use of educational technology to support student learning, and school restructuring and reform efforts. In the first paper, "Restructuring for Learning with Technology: The Potential for Synergy," Karen Sheingold argues that student learning can be successfully transformed only if active learning, adventurous teaching, and well-integrated uses of technology are brought together (21 references). In the second paper, "The Role of Computer Technology in Restructuring Schools," Allan Collins points out that the use of microcomputers as tools for students and teachers entails active learning, and will foster a change in society's beliefs to a more constructivist view of education (46 references). Christopher J. Dede considers three scenarios for future redesigned educational systems based on advanced information technology in the third paper, "Imaging Technology's Role in Restructuring Learning" (19 references and 3 appendices). In the fourth paper, "Restructuring and Technology: Partners in Change," Jane L. David argues that school restructuring and technology implementation require support and encouragement, plus the freedom, knowledge, and time to change (13 references). In the final paper, "How Structural Change Can Speed the Introduction of Technology," Ted Kolderie suggests that uses of technology and structure must change at both the school and school district levels to bring about urgently needed improvements in U.S. schools (13 references). (DB)

Restructuring for Learning with Technology

CENTER FOR TECHNOLOGY IN EDUCATION
BANK STREET COLLEGE OF EDUCATION
&
NATIONAL CENTER ON EDUCATION AND THE ECONOMY

Restructuring for Learning with Technology

DECEMBER 1990

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Contents

Foreword

The papers in this collection were developed out of a joint effort of the Center for Technology in Education at Bank Street College in New York City, and the National Center on Education and the Economy in Rochester, New York. For some time, we have been interested in the unique opportunity presented by three developments in relation to education — advances in our understanding of student learning, and of how to create educational environments that foster students' thinking and engagement; the potential of currently-available and future interactive technologies to support student learning and thinking; and restructuring and reform efforts that have at their core a commitment to higher-order learning and thinking for all students. At the same time, we were struck by the difficulty of bringing these three strands of ideas and activity together — either conceptually or in practice. With the formation of the national center at Bank Street, it became possible to involve a diverse group of people in wrestling with these issues. At a small conference in January of 1990, a group of us from the relevant communities (research, practice, policy and technology) worked hard to find the productive intersections of restructuring, technology and students' active learning. The papers in this collection were informed by the work of this conference.

Following the conference, each author was asked to integrate these three topics into a paper on restructuring for learning with technology. Not surprisingly, and despite the common assignment, the papers emerged distinct. Each author came at the problem from his or her own perspective and expertise, and tried to stretch to include arenas about which they did not feel very knowledgeable. In many ways, this effort mirrors what will have to happen on a much larger scale if these three agendas are to be integrated. That is, people who are working from different perspectives will have to make a real effort to grasp others' perspectives and integrate them into their own work. It is our hope that this set of papers can contribute to such a process.

Overview of the Papers

In the introductory paper, **Karen Sheingold** argues that, if student learning in schools is to be successfully transformed, the three agendas — active learning/adventurous teaching, well-integrated uses of technology and restructuring — must be brought together. While this is a propitious time for each agenda to be advanced, none will likely move forward very far in the absence of the other two. She provides examples of places where the hoped-for synergy can evolve, and makes some recommendations for how schools, districts and the media might promote such synergy.

Allan Collins argues that, because the nature of work is changing to incorporate computers in many aspects, the nature of school work will make a parallel change. Computers will come to be seen as necessary tools for students and teachers in their school work. All of these uses are subversive to the prevailing information-transmission view of education. Using computers entails active learning, and this change in practice will eventually foster a change in society's beliefs to a more constructivist view of education. He also proposes a set of district-level design principles for facilitating innovation in schools.

While technology may or may not guide or subvert education by itself, it is useful to consider how we might redesign schooling, given a not-too-distant set of advanced technologies, and a set of assumptions about learning and organizational design. How could these go together, if we had the opportunity to redesign schooling?
Christopher Dede considers three future scenarios for a redesigned educational system that illustrate what an integrated approach could make possible. He argues that a complete transformation of schooling is necessary, and that the use of advanced information technology is essential to the success of school restructuring. He proposes a set of research, practitioner and policy initiatives for moving ahead.

Future perspectives are centrally important for expanding our visions and informing long term plans. But if restructuring and reform are to provide the opportunity to use technologies well for student learning, we must look at where schools are now and at what it really takes for people in school systems to change how they do their jobs. From her vantage point studying schools and systems that are restructuring, as well as some that are implementing technology in innovative ways, **Jane David** analyses what it will take to make restructuring and technology a reality in schools. She argues that the same requisites apply to both restructuring and technology implementation — support and encouragement to invent new ways of doing things, plus the freedom, knowledge and time to learn to do things differently.

At the same time that we need to consider what happens inside of schools and districts, a broader policy view is critical for considering what is required to change the structure of the larger system so that it can support and foster innovation.
Ted Kolderie argues that there is currently an 'ecology' in schools of mutually-supporting approaches to teaching and learning, uses of technology and structure. Most approaches seek to change one of these at the school or district level, on the assumption that the others will follow. But it is the whole ecology that must change, and there are as yet no strong incentives for districts to change. He proposes that states withdrawing the exclusive franchise of the district to operate schools will create the necessary incentives and conditions for comprehensive changes to occur.

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Karen Sheingold is a director in Research at the Educational Testing Service in Princeton, New Jersey. Most recently, she was Director of the National Center for Technology in Education at Bank Street College of Education, a research and development center funded by the United States Department of Education. For the past decade, her research activities have focused on how technologies can contribute to the redesign of learning, teaching and schooling, and on the barriers to doing so. Prior to coming to Bank Street, she studied the development of cognition and memory in children. She has co-edited a recent book, *Mirrors of Minds: Patterns of Experience in Educational Computing*. Dr. Sheingold holds a B.A. in sociology and anthropology from Antioch College and a Ph.D. in developmental psychology from Harvard University.

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Restructuring for Learning with Technology: The Potential for Synergy

Karen Sheingold

The successful transformation of student learning and accomplishment in the next decade requires effectively bringing together three agendas — an emerging consensus about learning and teaching, well-integrated uses of technology and restructuring. Each agenda alone presents possibilities for educational redesign of a very powerful sort. Yet none has realized or is likely to realize its potential in the absence of the other two.

There have been attempts to make each of these agendas, in some form, part of the educational system for many years, to little effect. Yet there is reason to think that things may be different now.

In the past, approaches that consider students active learners, and that aim for students to understand academic content and be able to think, were seen as important for only selected groups of students (Resnick, 1987a). Now, in contrast, these goals and approaches are urged as priorities for all students. The broad consensus emerging about these ambitious learning goals and methods, supported by a body of research on how people learn, both demand and make credible a more widespread commitment to this approach than has thus far been attempted.

Similarly, in the past technologies have been claimed by some to be 'the answer' for education (Cuban, 1986). These views have now been widely tempered by an understanding that it is not the features of the technology alone, but rather the ways that these capacities are put to use in human environments that shape their impact. At the same time, the technology itself has changed. Computer-based and video technologies are more powerful and versatile than what preceded them, and much more widely available in schools than are earlier technologies. Their pervasiveness in the adult world of work has given them a new legitimacy in school. What's more, a growing cadre of teachers is learning how to use them well.

In a parallel manner, reforms of many kinds have continually cycled through American education (Cuban, 1990). Reforms in recent memory, for example, have called for 'injections' of new forms of curricula or teaching methods, or for more stringent adherence to standards. In contrast, proponents of restructuring argue that unless the system itself changes in a fundamental and thoroughgoing way, no reforms can be successful in the long run. Restructuring provides a framework for changing the

system as a whole, thus creating an environment within which particular reforms may be carried out successfully.

In the remaining pages I further define these three agendas, lay out the opportunities and challenges each presents, and discuss how the comprehensive advance of each requires the other two. I provide examples of places where these agendas are beginning to come together, and make some recommendations about how the process might be advanced. In the attempt to discuss these three agendas in relation to each other in a paper-length document, many relevant issues (e.g., assessment, accountability, incentives, uses of technology to promote restructuring independent of student learning) have been necessarily neglected. Some of these are discussed in the four remaining papers.

Consensus on Learning: The Opportunity

Educators and policymakers nationwide now recognize the critical need for students to learn how to think, to understand concepts and ideas, to apply what they learn and to be able to pose questions and solve problems. Such goals, once confined to our best public and independent schools, are now deemed appropriate, indeed mandatory, for all of our nation's children. These goals represent standards that are not simply higher than current ones, but qualitatively different. It is not more of the same we are after, but much more complex and rigorous standards of academic accomplishment.

The realization of the need fundamentally to alter approaches to teaching and learning comes from many quarters. The recent Governors' Task Force on Education report (National Governors' Association, 1990) emphasizes that students must learn to use their minds well in school, and points out that radical changes are required to redo the school curriculum. Textbooks and curriculum, they point out, "focus largely on the mastery of discrete, low-level skills and isolated facts, and deny opportunities for students to master subject matter in depth, learn more complex problem solving skills, or apply the skills they do learn." Similarly, those who are working on comprehensive redesign of curricula (American Association for the Advancement of Science, 1989), who analyze how students are doing in any particular subject (National Research Council, 1990), or who conduct national assessments (Applebee, A., Langer, J. A., & Mullis, I. V. S., 1986; National Assessment of Educational Progress, 1985), all come to very similar conclusions about what our students ought to be learning that they are not, and about the changes that must occur in how students learn.

As educators and policymakers put forth the urgency of these new goals for student accomplishment, they often acknowledge that these goals rest on a quite different model of what teaching and learning are about (e.g., Shanker, 1990). Effective learning hinges on students' active engagement in constructing their own knowledge and understanding. Such learning is not solitary, but occurs through interaction with and support from the world of people, objects and technologies of many kinds. By this model, teaching involves less telling and more supporting, facilitating and coaching of

students. And learning itself is not about a stable body of facts and truths, but rather about knowledge that is itself dynamic, that humans have created.

This set of assumptions is alternately referred to as 'student-as-worker,' 'student-centered' or 'constructivist.' For the purposes of this paper this approach will be termed active learning/adventurous teaching (See Cohen, 1988, for "adventurous teaching"), to acknowledge from the beginning that both learning and teaching are under revision.

What Does It Take?

What would it mean to create classrooms where these goals and approaches are seriously pursued? Research in recent decades has informed us about the kinds of classroom circumstances that help students to develop deep understanding of academic content (e.g., Brown, Collins, & Duguid, 1989; Chipman, Segal, & Glaser (Eds), 1985; Resnick, 1987b; Resnick (Ed), 1989; Segal, Chipman & Glaser (Eds), 1985). Students should engage in complex tasks (such as conducting a science experiment, composing a poem or analyzing the causes of economic decline in their local community) that enable them to participate in the many processes that comprise intellectual accomplishments. These should be tasks that, by and large, do not have one right answer, or only one route to solution. To the extent possible, students should engage in work that has a purpose that is understandable, even compelling, to them. Authentic and legitimate work, and work that has real connection to the world outside of school, is likely to be engaging and memorable precisely because it matters.

Moreover, because students come to school with markedly different backgrounds, interests and skills, learning must be individualized much more than a typical lesson format allows. This doesn't imply that students should spend all of their time learning alone. To the contrary, small group and collaborative learning are effective methods for accommodating and addressing differences in students' understanding and skills, as well as for involving them in complex and challenging tasks. But this point does suggest that the lockstep approach to learning (that is, everyone in the same grade learning the same thing at the same time in the same way) typical in most schools is likely to fail for many students. Schools must find ways of diagnosing students' strengths and weaknesses, devising programs that assure that they build on their strengths, pursue interests, cultivate new interests and get help where they need it.

In addition, classrooms will have to be places where all students can be deeply engaged in subject matter learning. Learning to think and learning content are integrally related. It is only through serious involvement with content that students can be helped and challenged to reason, question, integrate information from different sources and devise their own interpretations. At the same time, it is precisely through such 'higher-order' activities that students come to understand and remember information and ideas.

None of this is likely to take place unless students learn and develop in schools and classrooms where they feel safe, welcome, supported and respected.

The Challenge

The challenge that goes with these kinds of goals and approaches to student learning is profound. Over the history of education, these approaches have been the most difficult to achieve, and have succeeded only at the margins of the educational establishment.

Creating schools in which students are engaged in learning, and are learning how to use their minds well means asking teachers to do something that is very hard to do. It requires their both giving up a set of long-held beliefs about teaching and learning, and also devising and inventing instruction that embodies these new goals and approaches. Indeed, as David Cohen eloquently argues (Cohen, 1988), we know little about the instructional implications of the view of learning that pervades — implicitly if not always explicitly — current reform efforts. I his term 'adventurous teaching' appropriately conveys what is involved in doing such teaching, as well as what is entailed in becoming such a teacher.

This approach also requires schools and teachers to make very hard choices about curriculum. If students are to be held accountable for understanding, not just memorizing, for applying their knowledge, not just reciting it, for demonstrating their understanding through carrying out complex projects and doing their own research, then students must venture more deeply into a carefully chosen set of topics or concepts. Teachers and others will have to decide what curriculum deserves focused effort, and what can be ignored.

Similarly, many organizational features of schools come into question if this approach is taken seriously. For example, forty minute periods cannot do justice to the kind of work we expect students to do, and some of the information resources students need for their work may not be found within the school walls, but in the larger community or over telecommunications networks.

Clearly there is no single way to embody these assumptions, approaches and goals in a functioning school. There are teachers, principals and reform groups (such as the Coalition of Essential Schools) who are seriously taking on this task. But the field is genuinely open for experimentation, discovery and creation. Indeed, the possibility of success hinges on such openness.

The Need for Restructuring and Technology

What is required to advance this agenda in the nation's schools? First, a widespread public commitment to it from educational leaders and policymakers. More important than public statements and documents, however, is the real commitment to creating the kind of environment for schools and teachers in which innovations can be tried and supported (see David paper). In such an environment, people are encouraged to take risks, to learn from each other (and from those outside the system), to work hard at changes, which, whether they succeed or fail, can inform future plans and designs. Both of these conditions are met by restructuring as currently defined.

Finally, because active learning and adventurous teaching are so difficult to realize, schools and teachers will need to have abundantly available and make well-integrated use of technologies that can significantly support and advance this agenda.

Well-Integrated Uses of Technology: The Opportunity

While future technologies offer almost unimaginable capabilities to education (see Dede paper, this volume), even those currently available offer significant potential for supporting active learning and adventurous teaching. For example, computer software tools, such as word processors and graphing programs, can help organize and structure complex tasks for students. Video and videodisc technologies can provide visual examples of real-world phenomena, events and stories that then constitute a shared basis for student problem-finding and problem-solving activities. Computer networking technologies and satellite communications can help promote local and long-distance collaboration and communication among students and teachers, and can provide the means for students and teachers to become part of a larger community of scholars and scientists. Within classrooms and/or through networks students can create and have access to databases of information that can enhance their research efforts. Multimedia technologies can bring into the classroom much richer sets of materials for learning than are typically available in classrooms or school libraries today. These can contribute significantly to students' exploration and research. The production capabilities of computers and video cameras can enable students to create attractive, professional-looking products of their own design, which can be easily shared and revised. The public nature of computer work in classrooms can help to support collaboration, discussion and reflection. Some kinds of computer software can make visible and manipulable for students their own thought processes (e.g., the relation between a question they had and a piece of information they found), as well as concepts that have proven hard to grasp (e.g., what a median is). Others allow students to simulate and/or model complex scientific, economic or historical events and phenomena, thus exploring the variables and relationships that constitute these phenomena.

These uses can contribute to the kinds of classrooms we envision. Taken together, they can provide a resource-rich environment for our often crowded and resource-poor classrooms.

All of these uses are occurring in some schools in this country, as are other creative uses of technology that can support students' engagement, active learning and thinking. There is an increasing number of anecdotes and stories from the field about good projects, excited teachers and students and creative uses of technology. Educational technology magazines regularly report impressive stories about what teachers have accomplished with technology in their classrooms. Research evidence is beginning to accumulate that computer use in classrooms can support and help bring about active learning (See Collins paper, this volume).

In addition, a recent survey of a special group of teachers — those who had been nominated for inclusion in the study because of their accomplishment in integrating technology into their teaching practice — revealed that most of these teachers believe that their practice itself has changed as a result of using computers (Sheingold & Hadley, 1990). They indicated that they are able to present more complex material to students, that student work can proceed more independently and in ways that are more individually-tailored, and that they are acting more as coaches than as information providers in more student-centered classrooms. Importantly, for some of these teachers, the process of integrating the technology did more than enable them to change things in

their classrooms, it actually helped them to see that things should change, as well as how they could. It appears that technologies can help teachers to teach differently, and can perhaps present models for the more complex kinds of tasks in which students should be engaged.

The Challenge

Despite the promise that technologies offer to schools, and despite encouraging developments in some places, its potential is not being widely realized. Technology in schools has yet to be purposively tied to agendas for learning on a large scale. Computer-based technology has been brought into schools during the past decade largely because it was seen as important in and of itself — a central component of the world of adult work and of our children's future. Programming and computer literacy in secondary schools, and drill in basic skills in elementary schools, have dominated computer use in most schools (Becker, 1990). Only recently have applications — word processors, database management systems, spreadsheets, graphics programs — made their way into classrooms in significant number. And only recently have educators been attempting to integrate computers into subject-matter teaching and learning. But technology is not likely to have a qualitative impact unless it is deeply integrated into classroom purposes and activities.

The Need for Active Learning and Restructuring

This is where active learning and adventurous teaching come in. If districts, schools and teachers decided that the central (if not only) purpose of technology was helping to realize these goals and approaches, then technologies would have a comprehensive, exciting and forward-looking mission in schools. And a mission they are well qualified to take on. This purpose could bring focus and depth to their use, would enable schools to take advantage of the expertise of teachers who are already trying to use technologies to further these goals, and would likely have significant educational impact.

Giving technologies a serious educational mission in schools and districts is not sufficient, however. Once teachers begin to use technologies well to advance student learning, they often:

- need more time to learn about, gain additional training in and plan for use of the technologies;
- want students to have longer blocks of time in which to do their technology based work;
- want to integrate curriculum and try team teaching; and
- need greater access to more technology for themselves and their students.

The barriers these teachers must overcome (Dwyer, Ringstaff, & Sandholtz, 1990; Sheingold & Hadley, 1990) are precisely what teachers in restructuring districts have (or are supposed to have) authority to change.

It is very unlikely that the widespread and effective use of technologies to promote active learning can happen unless schools can reorganize their own structures, priorities and spaces. As with active learning, seriously pushing the potential of technologies requires a commitment to thoughtful innovation, and a school and district

community that supports such change. Restructuring can provide the context in which such innovation can take place.

Restructuring

Within the last decade there has been a near-universal recognition that our schools are not working for a very large proportion of our students. The list of indicators is long, consistent and depressing. Not only are students not learning the complex skills and knowledge they need to function effectively and productively as citizens in our democratic society and increasingly information-oriented economy. But many are dropping out long before they complete high school. Others, although present, remain lethargic, uninterested and not challenged by a system that rewards quiet, obedience and passivity.

A first wave of reform, based on the assumption that what was needed was higher standards defined by larger doses of the same sort of education (e.g., more requirements, a longer school day and year) has not produced significant positive results. A second wave is now proceeding, on the more radical assumption that what is needed is nothing less than a wholly reorganized system that operates on a different set of expectations and incentives.

What is Restructuring?

In practice, the term 'restructuring' means many things at the moment. The term is applied to phenomena as diverse as giving teachers more authority for school management, reorganizing a school's daily schedule, developing performance based assessments to measure student learning and creating ungraded classrooms. Either the term is ill-defined or refers to something so general that all of these phenomena qualify as part of it. Both are true. Yet an attempt at definition is critical, if restructuring is to mean, as it must, more than this year's special project.

The focal idea underlying many restructuring efforts is that the system itself, from top to bottom, must be reorganized in order to achieve the kinds of learning and thinking outcomes now seen as necessary for students. An organizational structure must be created in which authority and responsibility are aligned and in which those who are charged with getting the job done, namely schools and teachers, have the authority and support they need to do it well. In the long run, schools and districts must be accountable for achieving certain yet-to-be defined outcomes, rather than for adhering to a set of procedural guidelines and regulations. They, the educators, have the responsibility for deciding how they will reach these goals (David, Cohen, Honetschlager, & Traiman, 1990; Tucker, 1989).

Such an approach dictates a very different relationship between the central office and schools, because many decisions are pushed down to the school level. The central office then takes on a more supportive role towards the schools. Rather than telling them how to do what they must do, or whether they can do something, the central office helps them to get things done. Additionally, community participation is

seen as centrally important in setting the goals for the school system and, in some cases, in school-based decision making as well.

This systemic approach by itself says nothing about how schools shall operate or teachers do their work. It assumes that, given the authority, support and incentives, school staffs can figure out how to achieve the desired outcomes. It is hoped that, through such a structure, people's best efforts and energies will be mobilized and flourish. Over time, this outcomes-oriented system that respects teachers as professionals should lead to a much more productive educational system on a large scale.

The Challenge

The challenge of making the complex changes that are called for by restructuring is staggering. Virtually everyone in the system — superintendents, principals, teachers, students, parents, school boards and community members — must learn how to do their jobs differently. Resource allocations must be reconsidered, often by people who previously were not responsible for doing so.

What were formerly taken as 'givens' are now being reconsidered. What constitutes a school (no longer a building) is being called into question, as educators discover the importance of creating small communities within which students can be known and valued as individuals. Within schools, schedules, grouping practices, teaching assignments, the use of space, curriculum and assessment all must be rethought and redesigned. District and state regulations, formerly unscalable obstacles to change, are being waived for schools that can justify the waiver as necessary for their programs.

The Need for Active Learning and Technology

With all of this activity in the interest of systemic change, by far the most serious challenge for restructuring is actually changing what and how students learn in school. If this does not happen, restructuring will have failed to achieve its central purpose.

Thus, the ambitious goals for student accomplishment and radical approaches to reorganizing the educational enterprise must be met with equally ambitious and radical approaches to altering learning and teaching in the classroom. If it is qualitative change we are after, we must be willing to design and craft qualitatively different instructional practices and learning environments. The active learning/adventurous teaching approach, consonant with the goals currently put forth and with what we know about how students learn academic content and become thinkers, can guide, inform and itself be informed and expanded through the restructuring process.

Finally, if restructuring is to succeed on a large scale, it will need to take maximal advantage of tools and technologies that can support the process. It is unlikely that the ambitious goals for learning and teaching can be met without widespread, creative and well-integrated uses of technologies of many kinds.

Efforts at Synergy

If this argument is correct, then considerable synergy should result from the thoughtful bringing together of these three agendas. Each both requires and advances the other two. Considered separately:

1. Restructuring provides the expectations and organizational conditions in which genuine, well-supported and long-lasting innovation can occur and be self-sustaining;
2. High standards for student accomplishment and an active learning, adventurous teaching approach (well matched by newly-designed assessments and accountability systems) define both purpose and direction for the innovations; and
3. Technologies act as both supports and catalysts for the redesign of learning and teaching (and of the reorganization effort).

As of yet, evidence of such synergy is slim indeed. But that is not surprising, given the recency of all three agendas, and how challenging each is in its own right. Yet these ideas are making their way into a number of public forums — although more commonly as restructuring and technology, with the learning either implied or left out. In the last few years, increasing numbers of national conferences — including those for the educational community (Minnesota Educational Computing Consortium; National School Boards Association), and for researchers (American Educational Research Association) — have included restructuring and technology on their agendas. The National Education Association and the American Federation of Teachers have each been involved for several years with technology projects in support of restructuring, in collaboration with major vendors. The Coalition of Essential Schools has just begun an IBM-supported project to assist two of its schools in developing computer-based assessments ('exhibitions,' in Coalition terms) of student performance.

There are also schools and districts working on these issues. Everything is in its early stages; nonetheless, there are three types of examples I have been able to gather — technology schools in restructuring districts, a technology/active learning project in a restructuring district and whole districts making technology an element in restructuring.

Technology Schools

In some restructuring districts (e.g., Dade County, New York City, St. Paul, San Diego) technology schools are being created. New schools offer unique possibilities because they can start from ground zero and decide and design what kinds of places they want to be. Technology schools, in particular, are interesting because they can provide real examples of integrated use of technologies in environments where technology resources are plentiful, and where staff and students are interested in using them imaginatively.

In some districts, where new buildings are being designed for technology schools, there are exciting opportunities to think through the spatial implications of reorganized learning environments. For example, newly designed schools might have:

- teacher technology rooms, where teachers could have access to technology they use for their work and collaborative projects;

- spaces of different sizes and shapes for student individual work, small groups and large groups;
- special studios or spaces where students could do technology-intensive projects;
- electronic displays of student work in classrooms and public spaces.

There are two risks of technology schools, however. The first is that they may do on a district-wide level what computer labs do in some schools — relegate the technology to a place on the margins of the system. Thus integration is harder to achieve. The second risk is that they may represent a focus on technology per se, absent an educational vision.

School of the Future. A technology school with an educational vision, the School of the Future, has just begun its first year of operation in New York City's District 2. It came into being as a result of a grant from the United States Department of Education's Fund for Innovation. It is in a district where the superintendent has been supportive of schools that give the students in his district a variety of options for good education. All students in the district may apply to these schools. Starting at seventh grade, with 82 students, this school plans to add a grade each year through high school.

Before the school opened, the technology-sophisticated director created a vision for the school as a place where technology was used for learning. She hired six teachers, three of whom had technology expertise, and together they planned and continue to plan what kind of school it is going to be. They selected students who were interested in technology (though not necessarily experienced with it), who had 'stick-to-it-iveness,' and who wanted to work in groups. The ethnic composition of students was selected to match that of the district (30% Asian, 30% White, 20% Hispanic, 20% Black), and academic achievement was considered only to assure adequate diversity.

In the plan, there is an emphasis on students using technology to do projects, on students having time to get deeply involved in their work (100-minute periods) and on teachers being guides and coaches to the students. Teachers spent a great deal of time over the summer planning the curriculum (English and social studies are integrated into humanities), and were able to do some of their work over the Board of Education's network (NYCENET).

The school has a networked computer lab, where students take their technology class and are now learning basic applications. Once students master the basic applications (word processor, database, spreadsheet), the technology class and lab will be used for student project work. The school also has computers in the classrooms (6 for 28 students), a scanner, laser printer, video production equipment, CD-ROM drive and even an electronic easel that the school found abandoned in the old district offices. Eventually, students will be loaned computers to take home.

Although the plans for the school sound very different from that of most schools, the school is still bound by state and city requirements and examinations. It is approaching student assessment gingerly, planning first to work on alternative forms of assessing students in elective courses.

It is much too early in the school year to know how any of this will work out, but the teachers have been given a great deal of authority to design and redesign the

educational program in the school. They see themselves as learners as well as creators, and are taking an appropriately experimental approach to their new school.

Certainly, from the perspective of size, selectivity and resources, this school is starting out with many advantages. Some obvious barriers do not exist, or are lessened. But removing barriers does not ensure success; rather, it gives these teachers more time to focus on the central issues of learning and teaching. They will be faced squarely with a set of very hard problems about how to create a school environment that is fundamentally different from what they themselves have experienced. This school, therefore, represents fertile ground in which to grow a technology-infused, reorganized school that gives student learning high priority. What is not clear is whether or how what is learned in this school will affect any other restructuring efforts in New York City.

Technology Projects in Restructuring Districts

All districts have computers and related technologies, some in large quantity. In most districts, one can find special technology projects, often carried out by schools in collaboration with universities, and sometimes with hardware vendors. But there are few projects in restructuring schools and districts that are explicitly aimed at furthering both reorganization and active learning. The Discover Rochester (NY) project is one.

Discover Rochester. This research and demonstration project is entering its second year in a Rochester, New York middle school. The project involves collaboration among the Rochester City School District, the University of Rochester, the Rochester Museum and Science Center and the Center for Technology in Education at Bank Street College.

Rochester, an urban district with large numbers of poor students, is undergoing major restructuring. As part of this effort, it has reorganized its middle schools into houses, which are subdivided into grade-level clusters taught by teams of four teachers. The Discover Rochester project was carried out with a class of non-Regents eighth grade students last year, and will expand to more students this year.

The purpose of the project is to help students develop the thinking and problem solving skills necessary for directing their own learning and for communicating what they have learned. The interdisciplinary project incorporates subject-matter curriculum, and focuses on and takes advantage of the local community. Students are finding out about the Rochester environment from scientific, mathematical, historical, cultural and literary perspectives, working in groups to conduct research, and communicating their understanding via a multimedia museum exhibit. The exhibit, Discover Rochester, is created on Macintosh computers, and displays students' work through text, audio, graphics, music and maps. The exhibit has been on display in a local museum, the Rochester Museum and Science Center.

The project ties in very well with district pedagogical and organizational goals, which include the integration of technology into subject matter teaching, interdisciplinary teaching and schools as centers of inquiry that make use of community resources. Teachers agreed that students could devote one full day to this project, thus each giving up one period of instruction per week to it. The district allowed these teachers to waive accountability for their students' district-wide final examinations, freeing them from

having to cover the same amount of material in their regular courses. In addition, the district purchased the equipment needed for the project.

The one-semester pilot last year produced very encouraging results. Students were very engaged by the project, came to school more and participated in class much more than they had previously. Some gave up other time (e.g., lunch) to work on the project. They produced much higher quality work than they had before, and learned to use computers quite fluently (having had little or no previous experience). Through the project, they spent more time off campus doing their school based work, such as interviewing people, and gathering other kinds of information (e.g., photos at a local museum).

The teachers also became very involved in the project. Previously inexperienced with computers, they learned a great deal about technology. More important, the project provided them an opportunity to collaborate with each other and with project staff. They did so successfully, despite many differences in style and pedagogy. As teachers came to see and build connections between the Discover Rochester project and their own curricula, the project began to make its way into classrooms during regular class time. For example, in English class students spent a week reviewing what they had written for the Discover Rochester exhibit and planning their revisions. In addition, teachers became aware that a different kind of role was needed when working with students on the computers — more facilitative then directive — and that this transition was a very difficult one to make. By the end of the year, these teachers were better able to play a facilitative role, and were much more comfortable about it than they had been earlier.

It is encouraging also that new teachers, not members of the cluster team, have asked to be included in the project this year. The district views Discover Rochester as a lighthouse project.

Will the kind of synergy this project is creating lead to broader innovation of this kind in Rochester, or will the project simply disappear once the research is complete? We don't know. But if it continues to take hold and be successful in the eyes of the participants, it will put pressure on the system. As more teachers become interested and involved, they will need more technology, and will want to learn how to use it productively in their own subject matter classes. Some are already asking for this.

But teachers do not now have the authority to make their own technology purchasing decisions, or to allocate resources for their own training. Whether and how they will get the long-term support they need once the research project is completed is not clear.

A second way this project is putting pressure on the system relates to the issue of scheduling. Because students devote a full day per week to this project, and because all of the computers are located in the science room, complex scheduling problems have resulted.

As the project grows, a different accommodation of space and time will have to happen. Clusters of teachers may decide they need not one day per week for a special project, but for projects to become part of everyday life. In this case, periods may have to be longer than 40 minutes. And students may need special project development space where they can do their work.

Once some critical mass of teachers has become involved in using technology to promote students' active learning, they should be able to generate both practical solutions and exciting ideas for restructuring to more effective school organization and use of resources. Because it is taking place in a restructuring district, and if the project is to be the impetus for further innovation, the new demands it creates should be seen as opportunities for inventing new forms of schooling within existing schools.

Technology in District Restructuring

While large districts have yet to take the lead in making technology a widespread and integral part of restructuring, there are two small districts in which both technology and an active learning/adventurous teaching approach are being attended to — the Chittenden South School District in Vermont and Central Kitsap in Washington.

In Chittenden South, a rural Vermont district with 3000 students, restructuring and technology have been proceeding on parallel tracks. The schools are involved in an effort to restructure around a set of what they term 'essential learning behaviors' for students, goals that a committee of teachers designed. They want their schools to be places where learning, not teaching, is emphasized. At the same time, a very active technology program for the schools, run by a group of teachers and one administrator, has resulted in extensive use of computer and video technologies in the district.

The two strands of activity will intersect in the process of planning a major addition for a K-8 school that will house 1000 students when the addition is completed. A team of teachers has been chosen to plan and pilot the new program, to begin in fall of 1991, when these teachers work with 100 students in groupings that are multi-aged and non-graded. The roles for technologies in that school are under discussion, but there is a commitment to having lots of technology in the new addition (a 5:1 student to computer ratio). As seems to be the case in many other districts, the very physical reality of the new addition has created an opportunity to infuse the system with more technology. What is most interesting, though, is how the technology and learning agendas will intersect with and affect each other.

At the other end of the country, in Washington's Central Kitsap School District (11,000 students), restructuring efforts are underway. In the last few years, there has been a move to site-based management, and responsibility for all schools to develop their own operating plans. With fully half of the teachers involved, an overall plan for restructuring the district has been developed. There is a significant commitment to technology in the plan, a commitment funded largely by a local bond issue.

How did technology get into the plan in the first place? The core group of leaders (mostly teachers) who thought about and planned the district changes were strong advocates for both restructuring and technology and themselves technology users. The coordinator of the planning process is among these.

The plan is pedagogically eclectic, and varies among schools, although there are plans for a networked system of computers for all schools, at least for the teachers, within the next two years.

A central focus of the effort is on teacher support and training. There are many teachers in the district who are not experienced with technology. An elementary school opened last year that had few computer-using teachers, but at the same time provided a

computer for every two students (6 each per classroom plus 2 labs, and a computer on each teacher's desk). The computers were networked and were used primarily as a delivery system for instructional programs. Over the course of the year the teachers became acquainted with the technology, and made extensive and enthusiastic use of the electronic mail feature, which allowed them to 'talk to' each other and to keep track of what was happening in the school. Interestingly, the teachers are now asking for more sophisticated, more interactive programs for their students.

In two other elementary schools, multimedia technologies will have a major role in the instructional program. In one, for example, teachers will work in teams to organize curriculum around themes during a common planning time. They will use technologies to create multimedia problem-solving stations on one of these themes. Students will work in groups cycling through these stations, while teachers are available as facilitators. Almost half of the teachers in this school are involved in this program, and they will train their colleagues.

The restructuring and technology efforts continue to work together in this district, with the extensive planning and training effort still in progress. What is very impressive at the outset is the commitment to working on these agendas together, and then to providing enough technology and enough support that many teachers can become knowledgeable users. That way, large numbers of teachers can intelligently experiment with and push the boundaries of technology use for change in their district.

Recommendations

These examples aside, the integration of restructuring, active learning and technology is not yet occurring on a large scale. Why not? At least because all three developments are relatively recent, and because bringing them together is not easy to do. Perhaps over time these agendas will come together on their own, or, as Allan Collins argues, increasing use of technology will naturally move schools in the direction of active learning. But the situation is too urgent and the opportunities too great simply to wait and hope. Here are a few recommendations that may move the process along.

1. Bring technology and learning to the same 'table' when restructuring is being planned.

As it stands now, these agendas are on separate tracks in most districts, and technology is not harnessed to restructuring. So, for example, teachers can decide on a set of learning goals for the district, and not ask (or be asked) about how technology may advance or support these goals. At the same time, technology specialists can decide to spend money on technology they believe will be useful, and not ask (or be asked) how this purchase relates to the newly-defined goals. Unless both agendas are held accountable to and participate in the larger restructuring efforts, the opportunity for synergy will be lost.

Chances are very high that, in any district, there are teachers or computer coordinators who are expert at integrating technology into classrooms — who are

knowledgeable about the intersection of technology and classroom practice. Such people should be sought out and included in the process; they will have a great deal to contribute.

2. Reconsider how technology is organized in the district.

Are there structural ways to bring technology closer to learning goals? Technology budgets and authority could be more decentralized, so that schools or groups of teachers that want to invest in technology may do so. Or, if technology remains part of the central office, it could be linked directly with curriculum and instruction. Alternately, a committee of teachers could be making key technology spending decisions.

How technology monies are spent, and the process by which those decisions are made, is a critical issue. If technology is thought about as a tool for restructuring, then hard questions must be asked and hard choices must be made. For example, if a restructuring school has some significant number of dollars to spend on computers (or wants to raise money for technology), should money be spent on:

a. a system that can help to individualize students' schedules and activities, by managing and representing this information in ways that are easily accessible and usable to students and teachers;

b. a teacher network in the school, with computers on each teachers' desk, so that teachers can communicate and plan together more easily;

c. 'loaner' machines that teachers who do not own computers can take home to become more expert with the technology;

d. a multimedia laboratory, with computers, videodisks, CD ROM players and peripherals that enable students and teachers to create their own presentations and products; or

e. more classroom machines, so that the technology can become better integrated with students' ongoing work?

Clearly, there is no one right answer. In fact, all of the above could be the solution. But laying out and considering these options in relation to local circumstances and goals for restructuring, learning and teaching should be a key discussion. The result will have significant impact.

In addition, technology demands much more than hardware, software and technical support in schools and districts. It needs people who can help teachers integrate the technology into their practice. These may be computer coordinators, media specialists, other teachers or outside consultants or groups that provide such services. But schools and districts need to cultivate resident capacity of this kind. Once teachers have become competent with technology, plans for and discussions of how to use it are really about learning and teaching, and about how to tailor technologies to the needs of individual teachers and students. In-house support from colleagues will be of greatest long-term value.

3. Work towards a critical mass of technology and teacher expertise in using it.

Technology can support active learning and restructuring in schools and districts. But only if there is enough technology and, just as important, broad enough expertise in using technology for teaching and learning. Once there is a critical mass of teachers and administrators who understand how they can use technology to support

active learning, they can together think through and implement the structural, organizational and curricular changes they want to make in the school (and perhaps also the district). Without such a critical mass, efforts at widespread technology-infused change will flounder.

What constitutes a critical mass of technology expertise? There is little evidence on which to make a judgment. Nonetheless, I speculate that if half of the teachers in a school were comfortable with using technology in their teaching, and did so with some regularity in a variety of curricular areas, there would be a sufficient critical mass of expertise. Teachers could then help each other with the technology use and could think together about the kinds of innovations they want to implement.

As for technology, the critical mass is not defined solely by numbers of computers or other technologies, but also by where they are located, who has access to them and how they can be used. For example, a large number of computers used solely to step students through a programmed set of drills for a given number of minutes per day will not be enough. These rigid uses do not give students or teachers the opportunity of being in control of the technology, or of discovering and designing ways to use it for students' active learning.

On the other hand, one could take the same number of computers, provide software and peripherals so they could be used in multiple ways, and place some in classrooms, some in project work spaces for students and teachers, and some on the desks of interested teachers. With this configuration a critical mass of technology based experience could be developed and supported.

4. Use media to convey new images and metaphors of schooling.

If educators are successful in integrating these three agendas in the next decade, we can expect to have created schools whose students' achievements are both higher than and different from those of today's students. The schools where these students learn will look and feel different from what we generally think of as 'school.' These differences may create considerable discomfort for those of us who have grown up in traditional schools — that is, most of us. Whatever we may believe schools should be like, the traditional images are very powerful — teachers standing up in front of quiet children, students seated in straight rows, teachers telling students things. The images derive power from their familiarity.

It is very important, then, to cultivate new images of schooling, so that the new can become familiar and comfortable. The media can effectively portray these new images — small groups of students engaged in animated discussions about data they inspect on a computer screen; a student interviewing a senior citizen in the local community about local history while other students videotape the interview; a teacher and a student discussing and evaluating the contents of the student's portfolio of work, which includes products in several different media.

National media, particularly television, can be a powerful force in creating these kinds of images for the public. In small measure, they have begun to do so. But the need for such images far outstrips the investment made to date.

Local and much less expensive efforts may also be effective. For example, a Maine elementary school that is restructuring makes creative use of the talents of a retired citizen who volunteers his video services (Ray, 1990). He visits classrooms, tapes

children at work and interviews them. He also tapes their performances, plays, readings and artwork. His tapes are broadcast on the local access cable channel. Local parents not only have the pleasure of seeing their children on television, but also of seeing some new images of what school is — of what their children's school is.

Conclusions

I have argued here that these three agendas — active learning, technology and restructuring — each powerful vehicles for changing learning and teaching in schools — need the other two to be maximally effective. Indeed, the potential for synergy is very great if we imagine all three coming together in schools and districts.

Technology can work much more powerfully in schools if tied to learning and teaching purposes of the kinds we have described, and if encouraged and supported in environments where change, reorganization and reflective experiments are valued.

The active learning/adventurous teaching approach, similarly, can come into being on a large scale only when ambitious goals of the kind now being widely put forth for all students are actually meant, and in a reform environment in which schools and teachers are expected and supported to take serious risks to do their work more effectively.

Finally, restructuring cannot succeed unless its ambitious goals for student accomplishment and radical approaches to reorganizing the educational enterprise are met with equally ambitious and radical approaches to altering learning and teaching in the classroom. The active learning/adventurous teaching approach is the one most consonant with the goals currently put forth. Moreover, putting interactive computer and video technologies into the service of these learning and teaching goals can provide substantial support in reaching them. Put more strongly, it is unlikely that these ambitious goals for learning and teaching can be met on a large scale without widespread, creative and well integrated uses of technologies of many kinds.

What I am urging here is not just an effort at synergy, but at a coherence of educational goals, approaches, tools and structures that, even in very rough approximation, can transform schooling. I am well aware that each of the elements in this 'coherent' scheme is itself not fully formed. Therein lies great opportunity.

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The Role of Computer Technology in Restructuring Schools

Allan Collins

Trends

Computer technology and electronic networks have been slowly infusing the schools (see Becker, 1986). This equipment is unlikely to end up in closets or even sit idle most of the time, because of the widespread and growing use of such technology in both business and the home. Hence there is a kind of 'authenticity' (Brown, Collins, & Duguid, 1989) to using this equipment in the eyes of students and teachers; students want to use the technology because it represents the future. In a society where most work is becoming computer based, 'school work' cannot forever resist the change.

When a technology becomes widespread, whether it is the book, the automobile, or television, it has ramifications throughout society, including education. For example, the invention of the printing press and the book had profound effects on education (Boorstin, 1983; Eisenstein, 1979). It made the ideas of universal literacy and public schooling possible, and led to a deemphasis in teaching the art of memory. The automobile and bus led to the consolidation of rural schools and the dispersion of people to the suburbs, and in turn to the split between urban and suburban education, and busing to achieve racial integration. Television and video technology is even now having profound effects on education, such as the decline of print culture and the rise of a visual culture, low tolerance for boredom and the loss of innocence for children (Postman, 1982). Similarly the computer and the electronic network are likely to have profound impacts on education, and it behooves us to consider these as we think about the issue of restructuring schools.

There are two views of education that have been at war for centuries: the didactic or information-transmission view, and the constructivist view (Brown, Collins, & Duguid, 1989; Cohen, 1988a). The didactic view is the prevailing view among the general public. It holds that teachers should be masters of particular knowledge domains and that their job is to transmit their expertise about these domains to students by lectures and recitations. Students should memorize the facts and concepts of the domain, and practice the skills of the domain until they have mastered them, and they should be able to demonstrate their mastery on appropriate tests. The opposing

constructivist view, which is characteristic of Dewey, Vygotsky and Montessori, holds that teachers should be facilitators, who help students construct their own understandings and capabilities in carrying out challenging tasks. This view puts the emphasis on the activity of the student rather than on that of the teacher. Despite its predominance in the leading education schools (Cohen, 1988a), the constructivist view has made little headway in penetrating public education in America, or more generally in the world at large. But the trends I describe below may change that.

There are three different uses of technology in classrooms: (1) as tools for carrying out tasks, such as word processing, mathematical computations, programming languages, and electronic networking, (2) as integrated learning systems, such as WICAT has developed, which include a set of curriculum exercises that students work on individually and which keep records of student progress for guiding the student and reporting to the teacher,[1] and (3) as simulations and games, such as "Rocky's Boots" or "Where in the World is Carmen San Diego," where students engage in computer based activities designed to be motivating and educational. The argument in this paper is that the tool uses of technology are most likely to be the way computers are widely used in classrooms, and that integrated learning systems and simulations (though important for educational purposes) will only penetrate schools to the degree that tool uses provide a rationale for buying computers. So the trends discussed below assume the tool uses of computers, though they apply to other uses as well.

It is obviously difficult to anticipate all the effects of computer technologies, and it may well be that I will overlook some of the most important of these. But researchers have begun to observe how these new technologies are impacting the schools, so we can at least make some informed speculations. There are at least eight major trends that can be identified from the literature and from observations in schools where computers are being used by teachers.

1. A shift from whole class to small group instruction.

Where teachers use computers, normally one or two students are assigned to each computer. Teachers do not find it feasible to maintain all the students in lockstep, and so they move to an individualized instruction model of teaching (Schofield & Verban, 1988). This shows up in Gearhart, Herman, Baker, Novak, and Whittier's (1990) data on Apple Classroom of Tomorrow (ACOT) classrooms as a dramatic decrease in teacher-led activities (from over 70% of the time when computers are not in use to less than 10% when computers are in use) and a corresponding increase in independent or cooperative activities. This means teachers begin to talk to individual students, and develop an idea of their understanding and their confusions. Usually teachers have an inflated idea of what their students understand. So watching individual students struggle with problems may give teachers a better understanding of their students. It also means that students are more likely to go at their own pace and often in their own direction (Scardamalia, Bereiter, McLean, Swallow, & Woodruff, 1989), which for teachers can create problems of control.

2. A shift from lecture and recitation to coaching.

As part of the shift from whole class to individualized instruction, there is a shift from didactic approaches to a constructivist approach. Schofield and Verban (1988) document this shift in terms of language, where there is a shift from second person

constructions ("You should do this") to first person constructions ("Let's try this"). Gearhart, et al. (1990) document this shift in ACOT classrooms from teacher-directed activities (approximately 70% of the time off the computer to less than 10% on the computer) to activities facilitated by the teachers (from about 20% to 50%). The introduction of a third party, the computer, into the situation encourages the teacher to play the role of a coach in many of the same ways that a piano encourages the teacher to play the role of a coach in a piano lesson. Much of the learning is meant to take place between the student and the computer, and this puts the teacher into the role of observer and guide to make sure those interactions are beneficial to the student's learning.

3. A shift from working with better students to working with weaker students.

In whole class instruction, teachers carry on a dialogue with their better students (Schofield & Verban, 1988). This is because it is the better students who raise their hands to offer ideas. Teachers do not like to call on weaker students, because they do not 'want to embarrass them in front of the class.' In a classroom where students are working on computers, the teacher is naturally drawn to students who need help, who are generally the weaker students. Schofield and Verban (1988) documents that in one classroom where there were individual computers, two of the weaker students received four to five times as much attention from the teacher as the more advanced students. We see this same shift in the classrooms we have observed in New York and Cambridge. However, as Schofield (personal communication) points out there may be a tendency for the teacher to overlook students who need help, but do not ask for it, because the teacher is usually very busy in these classrooms.

4. A shift toward more engaged students.

In settings where computers have been put at the disposal of students in some long-term activity or project, researchers have reported dramatic increases in students' engagement (Brown & Campione, in press; Carver, 1990; Scardamalia, et al., 1989; Schofield & Verban, 1988). For example, Carver finds that students who were so bored with their classes that they would sleep through them, are eagerly engaged in a project to construct a HyperCard museum exhibit about their city. Similarly, Schofield and Verban report that students compare how far along they are in their geometry curriculum and even fight over who gets to use the computer during the time between classes. Dwyer, Ringstaff and Sandholtz (1990) cite several examples in ACOT classrooms where teachers were encouraged to do more activities on computers, because students were so highly engaged during such activities. It may be that the reported increases in engagement are due to the novelty of the computer, but it is unlikely that this accounts for the entire increase. To the degree that the computer supports long-term effort rather than short exercises (a shift that Gearhart et al. (1990) find in computer-based language arts, but not in mathematics), there is suggestive evidence from these studies that students become invested in the activities they carry out on computers.

5. A shift from assessment based on test performance to assessment based on products, progress and effort.

Assessment in most classes is based on students' performance on tests given after different sections of the curriculum are completed. The introduction of computer technology and the shift to individualized instruction (see above) moves assessment away from the classroom test, which seems inappropriate to teachers under the circum-

stances. Schofield and Verban (1988) report that the geometry teacher they studied moved toward assessing students based on the effort and progress they made: in that case the system would not let them go on until they had solved each problem. Where the teacher sets up a project based curriculum, then evaluation of students tends to be based on the products that emerge from the student's efforts. But for the present this creates problems for many teachers, because they do not know how to objectively assess such products. This problem has been solved for writing assessment in terms of holistic and primary trait scoring methods, and clearly some such scheme is needed for project based work (Frederiksen & Collins, 1989; Wiggins, 1989; Wolfe, 1987).

6. A shift from a competitive to a cooperative social structure.

In the normal classroom, students are working individually and competing against each other for grades, except where students drop out of the competition because of social pressures or repeated failure. Brown and Campione (in press), Newman (1990) and Scardamalia, et al. (1989) find a shift toward a more cooperative social structure in their classrooms, where a network provides a common database for students. Scardamalia, et al. report how students comment on each other's notes, telling what they find interesting and what they cannot understand. Dwyer, et al. (1990) report striking increases in cooperative behavior in ACOT classrooms as reported from the teachers' journals they collected. Gearhart, et al. (1990) found an increase in cooperative behavior in mathematics classrooms (from 10% of the time without computers to about 40% with computers), but essentially no cooperative behavior in language arts classrooms in either case. Even Harel (1990), who had fourth graders working independently to produce a Logo program to teach fractions to third graders, found students sharing ideas and expertise on how to accomplish certain things in Logo. However, Schofield and Verban (1988) found an increase in competition in the geometry classroom they studied, and it may well be that integrated learning systems generally encourage students to compete to get through the material faster. One study in Israel (Hativa, 1989) suggests that this depends on how easy the program makes it for students to compare their progress.

7. A shift from students all learning the same things to learning different things.

An underlying assumption of the educational system is that every student must learn certain basic knowledge and skills. This assumption leads to failing students who haven't mastered parts of the curriculum, and directing student's efforts to their weaknesses rather than their strengths (Drucker, 1989). The electronic network and shared database foster a different view of knowledge, where expertise is spread among different participants and brought together in a common space (Pea, in press). The National Geographic Kids Network (Foster & Julyan, 1988) is an embodiment of this idea of distributed knowledge, where students all over the country collect scientific data and exchange ideas with each other and working scientists. Because of the trend toward individualized education, there is likely to be a secondary trend toward breaking the lockstep of everyone learning the same thing in the same way at the same time. This trend can be seen in the classrooms described by Dwyer, et al. (1990), where students worked on different parts of complex projects, such as a model of their city; in the classroom described by Carver (1990), where students studied different aspects of their city to develop a museum exhibit; in the classrooms described by Scardamalia, et al.

(1989), where students conducted research on different social studies and science topics; and in the school described by Newman (1990), where students collected different data on the weather. So the lockstep approach in schools, where everyone had to master all of the same knowledge and skills, is likely to change with the advent of computer technology.

8. A shift from the primacy of verbal thinking to the integration of visual and verbal thinking.

As Postman (1982) has argued, the invention of the book transformed society from concrete, situated thinking to abstract, logical thinking. The visual media (i.e., television, cinema and computers) have begun to develop a new kind of visual thinking, and a number of educators (e.g., Bransford, Sherwood, Kinzer, & Hasselbring, 1987; Wilson, 1987) have begun to explore how to use visual media to enhance learning. The computer and electronic network potentially provide instant access to the world's accumulated knowledge, in both verbal and visual forms. This development may slowly undermine the primacy of the book, the lecture and their accoutrements, such as the multiple-choice test and the recitation class.

These effects of technology are subversive to some of society's most deeply held beliefs and assumptions about education. In particular they make tenuous the view that the teachers' job is to impart their expertise to students, and that the role of assessment is to determine whether the students have acquired the imparted expertise. So, inadvertently, technology seems to be coming down on the side of the constructivists, who have been trying to change the prevailing societal view of education, unsuccessfully to date.

Resistances to Technology

Cohen (1988b) and Cuban (1986) have argued persuasively that computer technology is likely to have little effect on the schools. They argue that to the degree technology is flexible, it will be bent to fit existing practice, and to the degree it can not be bent to fit existing practice, it will not be used. People interested in restructuring schools need to understand the resistances to change, some of which are particular to technology, and some of which are general, in order to identify the key leverage points on changing a well-entrenched system.

Any restructuring of schools can only take place over an extended period of time. The effects of the printing press were still being felt hundreds of years after its invention in the development of public education. So I will take a long-term view of how restructuring schools might take place and where a sustained effort is worthwhile.

Over the long term, important current issues, such as the costs of computer technology, its unreliability and teachers' unfamiliarity with its use, become non-issues. The costs continue to fall, and as computers become more integral to everything we do, this trend can only accelerate. It is a fundamental trend in economics that in relative terms the cost of goods decreases and the cost of labor increases (Drucker, 1986), so that compared to teachers' salaries, computers will appear incredibly cheap in the next century.

The problem of teachers' familiarity with computers will also decrease as people come to rely on computers for writing, calculating and communicating. This can already be seen to be happening: 'It is easier to type into a word processor than to write by hand.' It is easier to do your taxes on a computer than to do them by hand. And it is easier to send electronic mail than to post a letter. These uses will become commonplace among college students, secretaries and bookkeepers, so there is every reason to believe they will become commonplace among teachers. The problems of dealing with computers, such as getting them fixed, will become minor when they are used much of the time.

But of course the resolution of those kinds of problems does not mean that computers will be used in schools. Television is pervasive in society, and will probably never be widely used in schools. So why should computers come to be widely used when television is not? My argument is that the computer's most pervasive uses, which are related to work, are becoming necessary to accomplish school goals. Schools are in the business of teaching students how to read and write and calculate and think. As the computer comes to be an essential tool for doing these things in society at large, its use by students for doing these things is inevitable. We do not teach people how to drive cars by having them ride bicycles, nor will we teach people how to work by having them use paper and pencil, arithmetic procedures and library card catalogues, when work has become computer based.

There is a related argument that computers make the teacher's job more difficult, just as do television and film strips on the one hand, and the new science curricula of the 1960's on the other. The latter required teachers to put in extra time gathering materials together and saddled them with a difficult management problem of coordinating a class of students working independently on experiments or discussing the meaning of what they had done. It is true that computers make management more difficult when there are only a few computers in the classroom. The teacher has to figure out what other students will do when they are not working on computers, or has to allow a few students to miss a lesson while they work on the computer. But again, these are only problems in the transition to a society where most work involves computers. If students have ready access to a computer at all times, such as with a portable computer that can be connected to a network in different places, then these management problems go away. Students will do much of their work on computers instead of working with text books or worksheets. The management problem, then, is likely to be similar to that which teachers currently face when children are working individually or in small groups. To the degree the tasks students are doing with computers are more engaging than those they currently carry out with textbooks and worksheets, it will make the teacher's job easier.

Another argument against the widespread use of computers is that teachers are not willing to give up their control and authority over students to the computers. There are two aspects of this argument. One aspect is that teachers want to be masters of everything that comes up in their classrooms, and because computers contain more information than teachers can possibly master, they will lose authority. The other aspect is that teachers like to hold the attention of students, and if students are off working on their own, then the teacher has lost their attention, as well as control over what they are doing. The first issue is currently exacerbated by the fact that teachers do not know a

lot about computers, which as I argued earlier is a problem in the transition to a more computer-literate society. But there is a residual problem of giving students access to more knowledge than a teacher ever can master, together with the second aspect of students going off on their own. Both aspects of the problem of control can only be overcome by a changed view of the teacher's role to that of a facilitator of students' self-learning, rather than as a dispenser of information. Such a change in belief will not come easily, and will only come about slowly with the introduction of computers into school, as I discuss below.

Dwyer, et al. (1990) report a a difficulty that many of their teachers feel when they allow students to work on computers in ACOT classrooms. They seem to feel guilty that they are not teaching the students and they feel nervous about all the talking and sharing of information among the students. These feelings alternate with very positive feelings that the students are highly engaged and actively learning. So ACOT teachers in the initial phases tend to vacillate between enthusiasm for having students do a lot of their work on computers, and pulling back to use their old teaching methods in order to keep the class under control. Dwyer, et al. argue that it is important for teachers as they work through the transition to a more constructivist view of teaching to have the support of other teachers who have worked through or are working through the same transition.

Some people argue that teachers are not capable of using computers effectively. For example, in science labs they usually have students follow a fixed procedure (unlike scientific experiments), so that students know at each step what is supposed to happen. The argument is that when teachers use computers they will also follow a rigid format, since this procedural approach stems from a desire to make sure all students succeed. In fact, the computer-based integrated learning systems, such as WICAT's math curriculum, partially incorporate such an approach. This argument is surely correct to the degree that computers can be fit by teachers into their normal way of doing things. But the tools and simulations in computers are not content free. They make it possible for students to take over part of their own learning. To the degree computers support students' autonomous learning, and it is the goal of most educational software designers to do so, the particular pedagogical approach of teachers will be less decisive in determining how students learn.

A general view in organization theory is that American schools form a loosely coupled system (Weick, 1976) and while they readily adopt changes at the periphery of the system (e.g., model schools, computer labs), it is very difficult to make pervasive changes at the core of the system. While this may not be the reason constructivist teaching methods have failed to penetrate the schools (Cohen, 1988a,b), it surely will slow down any change that is introduced. But, if computers are widely perceived as necessary for school work, it will not stop their general adoption. In the next section I outline a set of principles designed to speed up adoption of any beneficial innovation.

Counterposed to the view that schools are a loosely coupled system, is the view that American schools have developed a system of institutions including the graded school, multiple choice testing, curriculum and materials, teacher education and lecture and recitation methods that are interlocking and self-sustaining. If you perturb any one of those parts of the system, the other parts will pressure the system to return to its original state. All of these institutions derive from and support a didactic model of

education. Cuban (1986) makes an argument of this kind in terms of what he calls "situationally constrained choice," which incorporates (1) school and classroom structures, and (2) the culture of teaching, including the beliefs of teachers. These work together in his view to restrict what teachers can do in adopting different innovations.

On this argument, if you try to introduce computers for students to do their work, then it will be sustained only to the degree it fits this prevailing institutional structure. Since computers undermine the lecture and recitation methods of teaching, and promote the student as self-learner, they do not fit this institutional structure, and will be squeezed out by it. Integrated learning systems, such as WICAT, have dealt with this problem by preparing curricular materials that fit easily into the current system. The materials mimic the kinds of test items in prevailing practice and so they produce gains on the tests that the current system embodies. They may have some early success in penetrating schools because they have tried to fit into the current system. But my argument is that it is the tool based uses of computers in society that will ultimately sustain their penetration of schools. The interlocking system described can certainly slow down the process, but it cannot prevent it, because the nature of education must inevitably adapt to the nature of work in society.[3]

Finally, there is a major resistance to the infusion of technology into the schools from the underlying belief structure in the society about the nature of education (Cohen, 1988a, 1988b). This didactic view of education holds that teachers must be experts in their field and that their job is to transmit their knowledge and skills directly to students. On this view learning involves memorizing essential facts and concepts, and performing procedures until they are automatic. The practices we cited above, such as the lecture and recitation methods of teaching, and testing for acquisition of facts, concepts and procedures, are manifestations of this underlying societal belief about the nature of education. The constructivist view, that education should attempt to create environments where students can construct their own understandings and skills, is held only by a small minority of educators, and has no chance of affecting practice until the underlying societal belief changes. On this view, technology will only be used to reinforce existing practices, such as drill and practice and multiple-choice testing.

I believe this argument is essentially correct and important for technologists to understand. But even if technology is allowed into the schools under the guise of reinforcing existing practice, once there it will take on a life of its own. It is important to stress that many of the tool uses of computers (e.g., word processing, mathematical computation, graphing of data) are quite compatible with current practice. Teachers will not object to students typing their essays, or even in the long run to their using computers to solve mathematical problems. Once teachers let computers in the door, then the kinds of effects described in the first section of the paper will occur and teaching practices will change. And just as a change in practices with respect to racial integration led eventually to a change in racial attitudes,[4] so a change in practices will slowly lead to a change in the educational beliefs of the society.

However, the arguments I have made so far only suggest that a change to a more constructivist education is likely to occur over the long run. A more salient question is whether there is anything that can be done to speed up the change. The next section proposes a structural change in school systems that would speed adoption of any change that improves educational practice, whether involving computers or not. The

final section addresses the issues of how technology can most effectively be deployed to foster educational reform.

Principles for the Design of a Self-Improving School System

A major problem is that the present structure of schooling militates against change. Students are assigned to schools and are required to go to them. If they are bad schools they will continue to exist: there is no way for them to fail. The only thing a school system can do to fix a bad school is to send in a new principal, and usually she is prevented from making many changes due to constraints of the situation.

Another problem is that it is difficult to start new schools successfully. The problem isn't that parents or teachers are prevented from starting schools, but that the incentive is for parents to keep their children in free public schools rather than paying for them in private schools. So the only schools that are started (other than those funded by foundations) are schools for wealthy parents. This is not where our major educational problems lie: they lie particularly among poor and minority populations.

What we need to encourage innovation is a system that fosters creation of new schools and allows failing schools to die, particularly in our large urban areas where the problems of American schooling are concentrated. Such a system would stimulate existing schools to do everything possible to insure their survival. We need incentives and constraints that operate to make sure that the most difficult students and problems are dealt with, and that natural selection operates on the basis of the quality of the schooling and not on some extraneous basis, such as the race of the school principal, the quality of the athletic program or the endowment of the school with facilities or technologies. A new system especially needs to avoid the current problem of creating schools that serve as dumping grounds for the educationally disadvantaged.

In order to facilitate innovations in schools, I would like to propose the following design principles. They are an attempt to synthesize the essential elements of various proposals that have been made for a redesigned school system (Chubb & Moe, 1990; Reigeluth, 1987; Tucker, 1989).

1. A mechanism whereby a group of parents and teachers in a school district can start a school.

The idea is that if parents and teachers in a school district want to start a school and they have a minimum of, say, 25 to 50 students, they should receive funds from the district at least equal to the current cost per pupil in the district. They also should receive space in a current building proportional to the number of students, from one classroom to an entire building.[5] Since there will also be costs associated with starting a school (money for books, technology, etc.), these should be provided by a special fund on a per pupil basis. This fund should also provide resources for expansion of schools to take on more pupils. In addition, the school district should provide staff for encouraging successful schools, either within or outside the district, to set up branches in the district.

2. A mechanism whereby schools are closed.

If an existing school loses enrollment below a certain minimum (say 20 pupils), then it should be closed, and its students forced to choose another school within the system (see below).

3. A national agency should provide information on each school to parents and children.

To make effective choices, parents and children need to be provided information relevant to the educational policy and success of the schools, such as the kind of information available in national guides to colleges (Reigeluth, 1987). This kind of information is best collected by a national agency to avoid dishonesty by local officials. The kinds of information the agency might provide include information about dropout rates, test scores of students in the school, college entrance and graduation rates of graduates from the school, random samples of opinions of former students and their parents, descriptions of the school's operation and facilities by neutral observers, occupation profiles of former students, etc. Ideally the test scores provided would be based on a 'systemically valid' testing system (see Frederiksen & Collins, 1989). Information should be provided to all parents and children who will be making a school-choice decision in the near future with respect to all the schools they might consider. Where a school is new, only a statement of intent is possible, unless it is a branch of an existing school or coalition of schools.

4. Students above some age level should be provided alternatives to further schooling.

If students wish to drop out of school above some age level, for example, 12 years of age (Sizer, 1984), then they should be allowed certain options. One option might be to leave school, if they can find full-time employment with a legitimate business enterprise. Another option might be full-time participation in a licensed program, such as a music camp or boy scouts. Most important, there should be a national alternative service program, such as VISTA, that will accept any student over the legal age. But students who take one of these options before age 18 should be encouraged once a year to enroll in a school of their choice to continue their education. As Drucker (1968) argues, we should be encouraging continuing education, where people receive education throughout their lives, rather than extended education, where they are kept out of the workforce through a longer and longer adolescence.

5. Schools should be allowed to select the students they prefer, but there should be incentives to choose hard-to-place students.

If the proposed system is successful, different schools will specialize in the kind of education they offer. This means that their educational policies will probably be more successful for certain kinds of students than for others. If the system restricts schools' ability to select their students, it will restrict their ability to specialize. This would undercut a major goal of the plan. That raises the problem that schools may all want to accept certain kinds of students and reject others. To offset this tendency, greater financial resources should follow the hard-to-place students. In fact, the resources need to be enough greater to offset the systematic preferences of schools, which suggests some kind of market mechanism. Both Reigeluth (1987) and Tucker (1989) have suggested such a mechanism.

These principles are designed to produce a system where there will be both individual schools and coalitions of schools with specialized goals. There might be technology based schools, art schools, Montessori schools, essential schools (Sizer, 1984), college preparatory schools, special schools for handicapped children, vocational schools, schools for girls, schools of design and engineering, schools for gifted in particular fields, back-to-basics schools, schools for particular minorities, bilingual schools and even comprehensive schools that avoid specialization.

This goes against a philosophy of having every kind of student in every school in order to foster overall integration of society. I would argue that specialized schools should be restricted from discrimination in the same ways that colleges and businesses are restricted.[9] But to the degree schools want to cater to students with particular interests or abilities, they may develop techniques that are particularly effective. The economic argument for the benefits of specialization applies equally well to schools as to business and labor. The moral argument against specialization loses force, given the inevitable disparity between urban and suburban school systems and the widespread tracking in the comprehensive schools.

One might argue that most parents and students will pick schools on the basis of proximity, or athletic ability, or better facilities, even if you provide them with information to make choices on the basis of educational quality. It is certainly true that most people will make their choices partly on such bases. But most people make choices by considering multiple factors, so that educational values are likely to be a factor to some degree in their decisions. The effect of proximity can be diminished by having multiple schools in each building, so that choices are made among equidistant schools. The effect of athletics could be diminished if we eliminated interschool athletic competition (as opposed to intraschool competition) in favor of Little Leagues or professional sports programs. The effects of facilities will be diminished if we equalize the distribution of resources on a per pupil basis as proposed in the first principle. To the degree school effectiveness is weighed at all in people's choices, it will bring a gradual improvement in the quality of schools. The more it is weighed, the faster the improvement.

Such a plan does not assume that parents know what is best for their children. There will undoubtedly be schools that emphasize drill and practice rather than thinking and that teach creation science rather than evolution, and these will appeal to many parents. But such problems are pervasive in the current system; over 80% of elementary school teachers think the phases of the moon are caused by shadows from the earth, and that the seasons are caused by changes in distance of the earth from the sun. The proposal does not solve these problems, but it would make it easier for people like Marva Collins (the Black woman in Chicago who started an academically-oriented elementary school) to start schools. I would argue that most parents would want their children to go to such schools if they were available.

Another argument against the plan is that rich parents will subsidize the schools they send their children to by various means and this will undermine the mechanisms for establishing educational equity and for placing less desirable students. If parents want to subsidize the schools, that is in fact all to the good: It will give schools more resources to improve education. Whatever parents contribute is not likely to unbalance the funding of education more than the current system of suburbs with high per pupil expenditures and cities with low per pupil expenditures. However, if equality in

educational opportunity is in society's interests, as I believe it is, then there is a rationale for offsetting parent subsidies with higher per pupil expenditures for schools that do not receive such subsidies. In principle, a market mechanism for placing less desirable students would automatically act to offset such subsidies, since the prospect of subsidies would enhance the value of students from wealthy families. So a market mechanism might be the least controversial way to offset parent subsidies.

One of the arguments that might be made against such a proposal is that it will produce a system like the college system in America, and colleges are not noted for their willingness to innovate. In fact, the most tradition-bound colleges, such as Harvard, are the most prestigious and therefore their practices serve as models for other colleges. This pattern inhibits the introduction of new practices, and serves to maintain the didactic approach to education that pervades the traditional colleges.

In organization-theory terms (Scott, 1987), the problem of educational improvement derives in part because it is difficult for consumers to tell a better product from an inferior product, unlike with restaurants and medical treatments. So in choosing colleges people rely mainly on prestige, and since prestigious colleges obtain the best students and most famous professors, they appear to be better on paper than their educational practices warrant. This effect tends to undermine the drive for self-improvement of any such plan in education.

However, I think it can be argued that in fact colleges have been much more innovative than the public schools in America and form the strongest part of our educational system. Certainly from the point of view of infusion of technology and flexibility with curriculum, colleges have been much more innovative. For example, there is more pressure on students in colleges to do their work on computers, and it seems likely that within ten years every college student in America will have their own personal computer. And when new disciplines emerge, such as psychology or computer science, they are much more readily adapted into the college curriculum than the public school curriculum. The continual birth and death of colleges encourages all colleges to seek their own market niches and to create programs that parents and children will find valuable. It is particularly among the less prestigious colleges, which serve the non-elites, that experimentation and improvement through natural selection occurs. In public schooling it is with the non-elites that our major problems lie, so that innovation is likely to occur where it is most needed under the proposed plan.

If a diversity of schools arises, and people are given the information necessary to make informed decisions, then the thesis of this paper is that the system will evolve toward better schools. The more effective schools will thrive and multiply, the less effective schools will die out. Existing schools and their personnel will do everything they can to enhance their chances for survival. There might evolve a preponderance of certain types of schools (e.g., essential schools), but that would only happen if they fulfilled the educational goals of a majority of parents and children. However, it is important to recognize that such a plan will not solve many of our schools' problems: it will only make it easier for change to occur in a very resistant system.

The Uses of Technology to Foster Educational Reform

The arguments in this paper have several implications as to what course of action school reformers and technologists should take to foster change in schools to make them compatible with the way society is changing. In the next century, an educated person will need to be able to learn and think in a computational environment. Most schools do not teach students these abilities now, and so a major change ought to be made in the way schools function.

One implication is that the first step is to put computers with powerful tool applications into the schools in as large numbers as possible. Many people might object to this step, particularly in light of the Apple Classroom of Tomorrow (ACOT) efforts, which have had at best marginal success to date (Baker, Herman, & Gearhart, 1989). They would argue that it is better to spend resources developing good educational software, teacher training or computer coordinators, in order to make sure the technology that goes into the schools is used effectively. The trouble with that argument is that it presupposes that good educational software or teacher training or computer coordinators will lead to more effective use. In a few cases that is true, but on a wide scale it is likely to fail. I would argue that if you have computers that are easy to understand and that are powerful for doing school work, then people will eventually figure out how to use them. Using computers effectively in schools is difficult because of all the resistances described above, and so most things you spend resources on to improve usage will not work. We should not expect efforts such as ACOT to succeed immediately. But society at large is making the transition to computers, and the massive educational effort to make the transition is reaching both students and teachers; Simon (1987) refers to this as "education by immersion." So my argument is to put powerful, easy-to-use computers into place, so that society's retooling of itself will have something to work with in the schools.

Let me also add that the most powerful educational uses of computers in the future may not be their tool uses. Rather, the uses of computers for simulation, reflection and video may be even more powerful educationally. But it is the tool uses that are becoming necessary to do work, and their usefulness to students and teachers will become readily apparent to everyone. The other uses of computers will come into play once computers have found their way into extensive use by schools:

- Computers as simulated environments: Computers allow students to carry out tasks they cannot normally carry out in school, from running a business or city to troubleshooting a faulty circuit. The possibility of doing tasks that are difficult or impossible to do in school is one of the major values of computers for educational purposes (Collins, 1990; Papert, 1980).
- Computers as reflective environments: Another powerful use of computers is for students to compare their own performance to other people's performances on the same task (Bransford, Franks, Vye & Sherwood, 1989). For example, in teacher education there might be a video segment of expert and novice teachers teaching some subject matter to students, with critiques on each lesson by experts from different viewpoints and explanations by the teachers of what they were trying to accomplish. Then a student teacher could compare a video of

their own teaching to those videos of other teachers (Collins & Brown, 1988; Lampert & Ball, 1990).

- Computers as video environments: There are vast video libraries of information that have accumulated over the last 100 years, and the output will multiply with the commercialization of the video camera. Video is a concrete medium, and people remember visual information more easily that verbal information (Bower, 1972). Having access to visual materials and explanations may well extend people's ability to learn, particularly those who have difficulty learning from books and lectures (Bransford, et al., 1987; Wilson, 1987).

In summary, because the nature of work is changing to incorporate computers in many aspects, the nature of school work will make a parallel change. This means that computers will come to be seen as necessary tools for students and teachers in their school work. But there are other powerful potential uses of computers for educational purposes. These uses will develop more slowly, but are likely to occur as computers become commonplace in schools and homes. All these uses of computers tend to be subversive to the prevailing didactic view of education in society. Using computers entails active learning, and this change in practice will eventually foster a change in society's beliefs to a more constructivist view of education.

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Endnotes

[1] In this category I include intelligent tutoring systems such as the Geometry Tutor developed by Anderson, Boyle, and Reiser (1985), whose use by students was studied by Schofield and Verban (in press).

[2] Indeed, it is hard to believe that we will continue to put children through the agony of learning handwriting, other than printing, when word processing is so much easier.

[3] This is not to imply that work is the only, or even the major, purpose of education; other purposes, such as citizenship or culture, are also important. But the undeniable importance of education for work means that there should not be a complete mismatch between them.

[4] For example, in 1959 southern Whites objected to sending their children "to a school where a few children are colored" by an overwhelming 72% to 25% margin, but by 1969 that ratio had reversed itself to 21% to 78% (Wattenberg, 1974). This reversal followed the Brown vs. Board of Education decision by the United States Supreme Court in 1954. All questions about racial attitudes among White Americans show similar shifts in the period following the legal changes that occurred in the decade from 1954-1965.

[5] In the Netherlands a new law permits 50 families to start a school. Experiments where multiple schools inhabit the same building are quite successful in New York City and Cambridge, Massachusetts.

[6] In fact any such system would spawn a variety of regulations, such as those colleges are required to meet to be licensed by the state.

Imaging Technology's Role in Restructuring for Learning

Christopher J. Dede

Imagine that you had the power to completely redesign every learning environment, every instructional situation, every educational organization. This would be a very exciting prospect, because our present schooling system is weighted down by the dead hand of past political compromises, mistaken theories, obsolete approaches and dysfunctional rituals. Given today's information technologies, contemporary knowledge in cognitive science and modern theories of organizational design, what would you create?

The first portion of this paper depicts my current visions on how technology could empower an evolutionary educational infrastructure for learning. Imaging strategic goals is central to reconceptualizing the purpose, content and process of schooling; if restructuring is merely a reaction against educational ideas that don't work, then the movement is doomed to failure. The core of developing a new paradigm for instruction must be based on insights drawn from the leading edge of practice in cognitive science, management theory and pedagogy.

My visions are shaped by my belief that the use of advanced information technology is essential to the success of school restructuring. Individualized learning and decentralized institutional structures require improvisational scheduling, flexible roles, accountability and incentives based on performance and the distributed coordination of interacting organizational processes. All types of organizations are finding that sophisticated computational and communications capabilities are necessary for orchestrating such complex operational practices. In addition, interacting with information technologies in school helps to prepare students for using the intelligent tools and interactive media that will pervade future workplaces and communities.

Once visions of desirable educational futures have been delineated, how can we get there from here? The challenge is to define a series of stepping stones that allow educators, learners and other stakeholders in an intelligent society to progress toward a technology-intensive paradigm for schooling. The second part of this paper outlines my sense of the actions needed now to start such an evolutionary change.

Overall, the flow of ideas through these sections models a process for reconceptualizing education:

- defining basic assumptions about learning, instructional technology and organizational development
- imaging visions of ideal teaching/learning environments based on design principles from these assumptions
- delineating actions in the present to initiate an evolutionary process that shapes these desired futures

The goal of this paper is to stimulate others to engage in a similar creative process for designing a technology-intensive culture that empowers learning. Through experimenting with a variety of different models, we can clarify our shared assumptions and goals and can build a critical mass for large-scale restructuring of schools.

My ideas come from involvement with artificial intelligence (applying advanced technologies to increasing human potential) and futures research (helping individuals and institutions cope with complexity and uncertainty). Like Ishmael in *Moby Dick*, I have wandered far, through many research labs and educational organizations, trying to synthesize what I've seen. What follows is meant more as a sketch than a blueprint; from this and others' visions, we could construct new types of organizations that markedly improve current educational effectiveness through technology.

Redesigning Schooling

Any image of the future is based on a complex web of postulates about the present. An inspirational scenario is often valuable less as a recipe for transformation than as a creative violation of our default assumptions about how things must be. The first step in evolutionary change involves building shared foundational beliefs from which we can construct desirable futures.

Delineating assumptions is important for any advocate of a new educational paradigm. Comparing the merits of alternate approaches to transforming schooling, or synthesizing their strong points, is very difficult unless each camp has clearly articulated design principles that underlie its visions. If the restructuring movement is to avoid degenerating into ideological factions that talk past rather than to each other, contrasting each side's beliefs about learning, technology and organization is crucial.

On what design principles do I believe restructuring should be based? In the past decade, researchers have developed new models for individualizing learning, prototypes for applying artificial intelligence techniques to instruction and innovative strategies for creating effective educational settings. Appendix A (Beliefs about Learning, Information Technology and Organizational Design) lists three sets of assumptions on which my vision and plan for action are predicated. Together, they form a partial set of principles to guide educational redesign and serve as the basis for the following images of optimal teaching/learning environments.

Visions of Redesigned Schooling

Below are vignettes illustrating how a technology-intensive paradigm could aid in restructuring educational environments to enhance learning. These scenarios are set in the early twenty-first century, when the advanced technologies described in Appendix B (The Evolution of Instructional Technology) are widely available. Brief commentaries before and after each image highlight themes in that vignette about shifts in the mission of schooling and its curriculum, organization, pedagogy, clientele, location, interconnections to other educational agents and evaluation methods.

The purpose of these scenarios is to illustrate, from a technology-based perspective, what functionalities we could attain in a couple of decades and how these capabilities could empower a new infrastructure for education. These visions neither show a perfect approach to schooling nor present a complete picture of a future educational system; rather, they indicate some of my current thinking on where redesign for educational evolution could lead us. Collective sharing of our images can lead to the synthesis of an overarching, dynamic vision that could serve as a goal for present restructuring efforts.

The Hangover

As illustrated by the assumptions about learning delineated in Appendix A, many ideas for improving education center on:

- enhancing individualization,
- students' active construction of knowledge,
- collaborative learning,
- delivery of instruction outside of school settings,
- situated learning,
- sophisticated evaluation strategies,
- pedagogical partnerships between teachers and intelligent tools,
- the use of visual representations for knowledge,
- distance learning.

The following scenario is crafted to suggest the capabilities of advanced technology for enabling these strategies for enhancing teaching/learning. This future vision depicts a few minutes of two students interacting through interconnected workstations.

> Karen sat down and punched her personalized megacard into her educational workstation, currently configured as an electronics diagnosis repair training device. When sign-in was complete, the workstation acknowledged her readiness to begin Lesson Twelve: Teamed Correction of Malfunctioning Communications Sensor. She used the telecommunications conferencing mode to link to Phil, her partner in the exercise, who was sitting at a similar device in his home thirty miles away.
>
> "Why did I have the bad luck to get paired with this clown?" she thought, noting a hung-over expression on his face. "He probably spent last night partying instead of preparing for the lesson." A favorite saying of the problem solving expert to whom she was apprenticed flitted through her mind, "The effectiveness of computer-supported cooperative work can be severely limited by the team's weakest member."

"Let's begin," Karen said decisively. "I'll put on the DataArm to find and remove the faulty component. You use the HKB (hypermedia knowledge base) to locate the appropriate repair procedure." Without giving him time to reply, she brought up an AR (artificial reality) window depicting the interior of a TransStar communications groundstation receiver and began strapping on the DataArm. The monitor's meshing of computer graphics and video images presented a near-perfect simulation, although too rapid movements on the screen could cause objects to blur slightly. Slowly, she 'grasped' a microwrench with her 'hand' on the screen and began to loosen the first fastener on the amplifier's cover. Tactile feedback from the DataArm to her hand completed the illusion, and she winced as she realized the bolt was rusty and would require care to remove without breaking.

Meanwhile, Phil called up the HKB for Electronics Repair; on the screen, a multicolored, three-dimensional web of interconnections appeared and began slowly rotating. He groaned; just looking at the network made his eyes hurt. Since the screen resolution was excellent, he suspected that last night's fourth margarita was the culprit.

Phil said slowly and distinctly, "Lesson Twelve," and a trail was highlighted in the network. He began 'teleporting' among the nodes, simultaneously watching a small window in the upper left-hand corner of the screen which was beginning to fill with data from the diagnostic sensors on Karen's DataArm. Delay time for the workstation's response was negligible, even though megabytes of knowledge were being scanned, thanks to the optical disc secondary storage connected to his instructional device.

Traversing the network at the speed with which Karen was working was difficult, given his hangover, and Phil made several missteps. "Knowledge Base," Phil said slowly, "infer what the optical memory chip does to the three-dimensional quantum well superlattice." The voice of his electronic coach suddenly responded,"You seem to be assuming a sensor flaw when the amplifier may be the problem." "Shut up!" Phil thought savagely, hitting the cut-off switch. He groaned when he visualized the cognitive audit trail of his actions feeding into the workstations of his teacher and the corporation's communications repair expert; he could not terminate those incriminating records.

Mentally, he began phrasing an excuse to send his instructors via e-mail at the end of the lesson. He knew that they would be very angry, for their salaries were determined in part by his performance. Meanwhile, Karen was exasperatedly watching the window on her screen in which Phil's diagnostic responses should have been appearing. "He's hopeless," she thought. Her consciousness sensor interrupted with a warning: "Your blood pressure is rising rapidly; this could trigger a migraine headache." "Why," Karen said sadly, "couldn't I have lived in the age when students learned from textbooks..."

The scenario focuses on one aspect of schooling's mission: preparation for the future workplace. In this particular instance, the students are learning a typical diagnosis-and-repair strategy for an early twenty-first century communications system. The technical curriculum in schools is implicitly depicted as centered on real-world problem solving through interdisciplinary approaches. These students are close to completing the curriculum — at least, Karen is — and are practicing skills for which they have already received extensive preparation.

By implication, the workplace for which schools are preparing students has changed dramatically. Instead of databases, users access nonlinear knowledge bases —

like the HKB — that contain some embedded intelligence. Tasks are typically assigned to groups rather than to individuals; in a global workplace, the members of a team may be separated by distance, as Karen and Phil are practicing. In this future, people accomplish some tasks using teleoperated robots and virtual environments, such as this artificial reality with gesture technology and tactile sensing devices.

This cooperative microworld with an embedded coach is capable of individualizing to multiple learning styles, involving students in active construction of knowledge and situating learning in contexts similar to those in which the skills will eventually be used. The reward system for each student and instructor in this situation is based on sophisticated measures of performance made possible by the technical advances described in Appendix B. For example, the device keeps a cognitive audit trail — an automatic record of user actions — that can be replayed to facilitate learning from errors.

The learners' ages are indeterminate, beyond the fact that they have formal reasoning capabilities; perhaps one is an adult retraining for a new career. The multiple instructors these students have — a teacher, a corporate practitioner and an intelligent coaching device — illustrate the diversity of resources available to facilitate learning, the team approach used in pedagogical situations and the involvement of stakeholders external to schooling.

The Network

This scenario depicts a teacher's interaction with a knowledge base that aids in fulfilling her responsibilities beyond classroom instruction. Based on the design principles in Appendix A, the vignette images several aspects of how restructuring could alter the teacher's role, the curriculum and school organization:

- people work in cognitive partnerships with intelligent tools
- power and responsibility for decisions are decentralized
- teachers' working conditions and respect from the community are improved by their use of advanced information technologies
- the curriculum is taught in an interdisciplinary manner by teams of instructors
- the site and schedule of instruction are flexible

Since teaching is as sophisticated and demanding a profession as medicine or law, this image also illustrates how the future school workplace could incorporate multiple amenities and creative challenges to attract skilled human resources.

> As part of a regional plan to build a middle school, the Department Head for Civilization has been asked to select a system for communications networks in the new building. She is taking the lead in making this decision because, of all the curricular areas, the Civilization group uses the most graphics, simulation, and cooperative learning — thus posing the greatest need for networking capabilities. An intelligent knowledge base is being used as a source of information and expertise in resolving this issue.
>
> This job performance aid serves as a clearinghouse on educational technologies, presenting to users projected and historical data on technological capabilities, business trends and societal developments that could affect the evolution of instructional devices. The information supplied is continuously updated and evaluated by a sophisticated environ-

mental scanning process. In addition, users of this 'information utility' can interact with each other and with experts, creating a global electronic forum for the exchange of ideas.

This intelligent knowledge base communicates with its users via the monitor (color images, computer graphics, text) and speech synthesis; hard copies of output are produced as needed. Users can query the knowledge base through the touch-screen, mouse and keyboard, using a restricted form of natural language. (For the sake of clarity in this scenario, all user and system actions are presented in non-restricted natural language.) When interacting with other people through a network, both computer conferencing and direct voice communication are possible.

A session is midway in progress; the monitor shows blueprints of the interior of the school, with a graphic overlay indicating equipment that could be installed and giving descriptions of each component. The Department Head is sitting in her office, with another hour to work on this task before her students (eighty children, ages twelve to fourteen) and the other teachers and aides on her instructional team return from their trip to the local barrio.

DH: Can this type of network carry enough data for the needs I just outlined?

KB: *(invokes a knowledge based system that specializes in this area)*

The bandwidth will allow bursts of data sufficient for normal classroom use, but intensive monitoring of individual students will result in slow performance.

DH: How likely is it that, in five years, we could upgrade the power of this network?

KB: *(calls up internal record)*

Last year's Delphi panel indicated a 60% probability of significantly enhanced power for this type of network over the next five years.

DH: How expensive would the upgrades be that might create such an advance?

KB: *(displays cost estimates in a spreadsheet format linked to the projected operating budget over the next five years)*

DH: How similar would this system be to the types of networking workers may use two decades from now?

KB: *(scans industry forecasts)*

In twenty years, the communications interface and protocols on workplace systems could be quite different. The networking approach you are now considering is close to maturation and will likely be obsolete in a decade.

DH: That would not be good preparation for our students. What are alternative technologies for networking systems?

KB: *(displays vertical chart of data transmission speeds for various technologies)*

DH: Show me these figures in a table.

KB: *(displays speed data in tabular form; knowledge base notes user preference as a default format for future requests)*

DH: Who are the network coordinators in the three closest middle schools that have recently implemented a fiber optic network?

KB: *(searches index: three listings appear on the screen)*

Here are the names you requested. You have no previous record of contact with Drs. Jones and Smith. You did interact with Mr. Brown three months ago; the topic of the discussion was erasable optical discs. None of these users are on line at the moment. Would you like to send messages to them?

DH: Yes.

KB: *(this user's standard format for initiating contact appears on the screen for editing; the knowledge base automatically sends the electronic mail when the user has finished wording the messages)*

DH: Which businesses in a thirty mile radius have recently implemented a fiber optic network?

KB: *(searches index; five names appear on the screen)*

Here are the names you requested. One of these, the Technology Coordinator in the Mayor's office, is also using this information utility at present. Would you like to videoconference with him?

DH: Yes.

(A video window appears on the Department Head's monitor with a real-time image of the Mayor's Coordinator. On his screen, both an image of the Department Head and a window with the blueprint she is studying appear. The two discuss the merits of this type of networking, using a telepointer to indicate where each is pointing in the WYSIWIS ["What You See Is What I See"] window. The Coordinator advises the Department Head that the Chair of the School Board is an advocate of a different form of networking technology; the Department Head replies that she has the final decision making authority in this situation. After five minutes, the two agree to meet for lunch next week and terminate the videoconference)

DH: How much more would fiber optic cable cost than twisted-pair?

KB: *(concludes from incoming physiological data and historical patterns of user's concentration span that her attention is wandering)*

Would you like to take a break first?

DH: Yes. While I get some espresso, build a cross-impact matrix template for me. I want to assess the likely consequences that shifting the networking strategy will have for home-school interconnections, the use of intelligent diagnostic devices, and the simulcast of Japanese athletic events during the biweekly four to five p.m. class session.

The vignette demonstrates how the advanced technologies discussed in Appendix B might be used in practice. As the scenario suggests, working with an intelligent tool requires less low-level data manipulation than using a conventional information system, but necessitates more higher-order cognition. The complex intellectual performance the teacher exhibits in this future vision illustrates the skills today's students will routinely need in the workplace they will inherit. Note the emphasis on long range thinking, the assessment of how an innovation may impact other parts of the organizational system and the focus on problem solving through interdisciplinary analysis.

The flexible roles that teachers play in the institution's decentralized administration are shown by the responsibilities — and power — the Department Head has. Differentiated staffing, flexible scheduling and the routine use of educational sites outside of the school make such distributed authority possible. Advanced computer-supported cooperative work technologies enable the complex coordination required and allow the involvement of external stakeholders (e.g., the Mayor's Technology Coordinator).

Both technology and organizational redesign have improved current working conditions: the Department Head has a private office, a sophisticated workstation and an espresso machine. Such changes are essential to attracting the skilled human resources this complex professional role necessitates.

The Seminar

Many of the design principles in Appendix A can be implemented without the use of information technology. This scenario indicates the limits of instructional devices, suggests some social inventions central to restructuring, and depicts the continuing central role of human interaction even in a technology-intensive educational paradigm.

> Dr. Hari Grosvenor sat on the floor with his students in a circle. Three 6-year-olds were trying to talk simultaneously. Each was somewhat impeded in the discussion by having to use Spanish (this part of the day was devoted to practice in a second language) but their enthusiasm was unhindered. To Hari's relief, only his handicapped student's instructional device was currently in the room; he hated information technology.
>
> Hari felt that intelligent tools had their uses, but not in his classes. The foundations for his pupils' discussion had been laid by technologies that trained them in the prerequisite knowledge, but only a human teacher could master the intricacies of teaching a seminar. His specialty was helping learners with low self-esteem feel capable, loved, motivated and challenged. Hari revelled in the freedom he had: to teach anything he wanted in any way he chose, so long as his students' sense of personal worth increased. His ability to assess individual learning style better than the most sophisticated diagnostic devices was being studied, but he knew that a machine could never replace him.
>
> From her vantage point at the far side of the circle, safely in the middle of her pressure pad, Ariel watched Hari deftly refocus the discussion. The scanner on top of her computer screen continually monitored Ariel's actions with her wooden blocks. Simultaneously, icons on the screen depicted her movements, text along the screen's bottom described her actions, and a synthesized voice in her earphones discussed what she was doing. Her congenital mental handicap was rapidly improving through this immersion in multiple representations of reality, from concrete manipulations to abstract symbols--plus the care of her teachers. Still, she liked her machine best of all right now; no person was as oblivious to her handicaps.
>
> Having intervened to stop his seminar from coming to blows over who should serve as their representative on the school's governing board, Hari's thoughts wandered. He wondered how he should spend his merit bonus; once again, his innovation quotient had been the highest in the school. "Computers slow down those other teachers and stifle their creativity," he mused. "I'm glad the next stage in the master plan for our region calls for less reliance on instructional devices. Biotech prosthetic enhancers are definitely the best thing going."
>
> Every school will have numerous learning settings that focus on interactions among people without technology intervening. In addition, technology is no 'silver bullet'; since all pedagogical techniques have their limits, some students will be unable to learn from instructional devices. Other pupils, like Ariel, will be able to achieve their full potential only with the aid of sophisticated intellectual prosthetics.

Hari's merit bonus for innovation and his freedom to control content and methods as a way of building learners' self-concept exemplify the types of organizational innovations essential for successful restructuring. The participation of learners in school governance is important, both because all stakeholders should have a voice and because this type of involvement is a good way to learn group decision making and democratic processes. As the scenario suggests, just when we are learning how best to

use information technology, along will come the biotechnologies to further complicate education's mission.

Summary

These vignettes convey a flavor of the ways information technology can empower restructuring for learning. However, while short scenarios are a good method for imaging the microstructure of a future environment, they are limited in portraying patterns of large-scale change. The effect is much like trying to visualize a wall-sized painting by examining the surface one square inch at a time. Hence, the scope of this study precludes giving the 'big picture' for educational restructuring.

These small scenarios also suggest the types of sophisticated skills today's students need for the workplace they will face as adults. Imagining civilization a generation from now may be as difficult for us as visualizing a commodities broker electronically monitoring soybean options would have been for eighteenth century farmers contemplating a steam tractor. The Industrial Revolution took more than a century to reach fruition; but global economic competition and the pace of technological advance will drive the next transformation in several decades.

We cannot leap directly to these images of the future—nor would we wish to, as they are doubtless mistaken in significant ways. Essential to the attainment of these visions will be overcoming the widespread misconceptions about instructional technology discussed in Appendix C. Correcting these false beliefs will be an important early step in creating an evolutionary process toward shared, dynamic images of schooling redesigned for learning.

A Suggested Series of Actions for Initiating Educational Redesign

One of the organizational assumptions in Appendix A indicates that, in evolving from its present state to some distant, desired goal, an institution must progress in quantum steps via stable intermediate structures. Each stage of evolution requires a critical mass of resources, must create a new organization more rewarding to its stakeholders than the previous stage and should shift the institutional infrastructure closer to the ultimate objective. Below are two incomplete lists of actions we should take to initiate such a restructuring process; their focus is on technology's role in empowering learning and organizational redesign.

Practitioner Initiatives

- Convene a representative group of influential leaders from education, business, government, media and the community to form a critical mass of resources to initiate large-scale innovation. The agenda would be to coalesce:
  - — collective design principles to restructure schooling for learning through technology.
  - — shared long-range visions for educational practice based on those principles.
  - — detailed models of the first stage of schooling's evolution, to be implemented at a variety of demonstration sites.

— a process for monitoring the evolution of these activities and periodically reformulating design principles and long-range visions.

- Mount a coordinated campaign to inform all stakeholders in high quality education both about why an immediate transformation of our current paradigm for schooling is essential and about the evolutionary process that the coalition above has initiated.
- Lobby all types of regulatory bodies that govern schooling for waivers from current regulations to allow experimentation with alternate paradigms for teaching/learning.
- Develop an overall research design for a set of high risk, high gain experiments with unusual institutional structures and innovative technologies. These studies would attack major problems that have been intractable in the current paradigm for schooling. For example, we could determine whether artificial realities created through information technology might undercut drug use by providing students with a different way of getting outside the stresses of their everyday environment. Other potential research themes include alternate methods for education to be accountable to society and new types of incentives for individual and institutional innovation. The restructuring coalition would distribute these projects among its participants to minimize costs and risks, but would centrally coordinate research designs and information gathering to maximize the knowledge gained.
- Devise technology partnerships between business and education. For example, corporations could help to develop innovative approaches for front-end funding of capital-intensive technology investments. Also, industry experts on implementing information technology in workplace settings could be valuable resources if loaned to schools.
- Develop less formal methods for credentialing educational achievement. As an illustration, cognitive audit trails embedded in workplace tools could document learning-while-doing activities.
- Include instruction on the intersection of learning, technology and restructuring in pre-service and in-service training. This instruction could focus on combatting the misconceptions about educational technology discussed in Appendix C. In particular, teachers could be exposed to prototypes of advanced instructional devices; this would illustrate both innovative pedagogical capabilities and the shifts in human skills needed for partnership with intelligent tools. By analyzing the outcomes of alternative implementation strategies, the importance of powerful hardware, long lead time and a critical mass of resources could be demonstrated.
- Form buying collectives that develop a set of specifications for advanced applications, then contract to expend a substantial amount of money if vendors develop products that meet those requirements.

Policy Initiatives

- Implement incentives to attract scarce human expertise into learning-related applications of artificial intelligence, computer science, cognitive science and organizational design. At present, few expert practitioners in those fields choose to become involved with educational innovation.

- Provide greater research funding for:
  - — sophisticated conceptions of human intelligence,
  - — innovative technologies for evaluating aptitude and achievement,
  - — empirical studies of tutoring and individual learning,
  - — new approaches to instructional design (for human teaching, standard computer-assisted instruction and intelligent tutoring systems),
  - — core human skills for cognitive partnership with intelligent tools,
  - — psychological and social impacts of the intensive use of instructional technologies,
- Develop better measures of the economic utility to our nation of investing in human resources. The American public has much more knowledge of how many resources schools consume than of the long-range costs of an ignorant society.
- Promote the facilitation of learning by educational agents other than schools (families, communities, workplace, media). For example, businesses could receive tax credits based on technology partnerships with schools that go beyond the donation of obsolete equipment.

These lists are illustrative rather than complete, but indicate the types of actions central to starting an evolutionary process of restructuring. Hopefully, papers such as this will stimulate a synthesis of agendas for action from many different perspectives.

Conclusion

Advanced information technologies are changing the knowledge, skills and values needed to be a worker, citizen and self-actualized human being. In a global marketplace, for America to regain prosperity, developing an accomplished and motivated populace will be at least as important as technical advances, partnerships between government and business, international treaties and decisive leadership. The quality of the nation's educational system is central to preparing us to best the challenges we face on the brink of the millennium.

Many have documented that present approaches to schooling are deeply flawed and should be radically changed. Comparing existing practice to the design principles in Appendix A illustrates that a complete transformation is necessary; almost every assumption underlying the current educational model is obsolete. Shifting to a new paradigm for teaching/learning is crucial to developing human resources for transcending our present malaise.

The use of advanced information technology is essential to the success of school restructuring. Individualized learning and decentralized institutional structures require complex organizational practices that necessitate sophisticated computational and communications capabilities. Stepping into a classroom should be like entering a time machine hurtling forward; today's educational system should foreshadow the intelligent tools and interactive media that will pervade future workplaces and communities.

A critical mass for large-scale restructuring of schools can be built through an iterated process of:

— defining basic assumptions about learning, instructional technology and organizational development.

— imaging ideal teaching/learning environments based on design principles from these assumptions.

— delineating actions in the present to initiate an evolutionary process that shapes these desired futures.

This paper presents my current beliefs, visions, and suggested initiatives. Through sharing our individual suggestions, we can collectively construct new types of organizations that markedly improve educational effectiveness.

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Appendix A: Beliefs about Learning, Information Technology and Organizational Design

Below are listed sets of assumptions about learning, information technology and organizational design. These summarize the basic ideas shaping my vision of schooling; design principles derived from these beliefs underlie the future visions described in the body of this paper. These lists are not meant to be exhaustive summaries of current knowledge; the references in the bibliography are illustrative sources that I've found useful in conceptualizing these foundational postulates.

Assumptions About Learning

- Learning involves an evolutionary series of progressively more sophisticated conceptions of reality. Learners interpret every instructional experience through an existing mental model; they are not empty vessels to be filled.
- New concepts and skills are best remembered and integrated with existing knowledge if learning is active and constructive rather than passive and assimilative.
- Education must begin by making learners feel capable and motivated and challenged. In addition, basic needs deeper than learning (safety, hunger, love) must first be met.
- Learning is motivated by multiple factors, including intrinsic curiosity, social interaction, extrinsic rewards and the joy of accomplishment. Because of this mixture of motivations, cooperative learning in groups is sometimes the optimal strategy; in other situations, individual learning is superior. Often, the ideal environment for learning is very diverse, mixing different ages, developmental levels and cultural backgrounds.
- Learning is dependent on an individual's beliefs and attitudes. For example, understanding a student's cultural perspective is vital to communicating knowledge and measuring learning.

- Each individual has a unique style of learning, based on cognitive, sensory, psychomotor and social factors. Tailoring instruction to this style is vital for educational effectiveness. The material an individual is capable of learning is dependent on developmental level. At early ages, the more abstract representations educational technology can present are less useful than in later years when formal reasoning skills have evolved.
- The activities through which learning takes place and the context in which learning occurs are integral parts of the knowledge gained. Educational effectiveness is enhanced by situating learning in an environment similar to that in which the knowledge will be used.
- Once learners have mastered the fundamentals of a subject, using an interdisciplinary approach to subject matter is more effective than breaking material into the traditional disciplines, because real-world problem solving involves comprehending richly interconnected systems.
- Each step in learning requires time for reflective ideation. Compressing the time necessary for an individual to master an educational experience results in little or no learning. Learning is continuous and unbounded; people who treat every situation as an opportunity for growth learn more than those who limit their education to classroom settings.
- Much of an individual's ultimate capacity for personal growth is determined prenatally and in the first five years of life. Developing the learning capabilities of children must begin long before they reach kindergarten.
- Very few people are currently achieving close to the level they could have attained if their true potential for learning had been realized. Society benefits most from an educational system that seeks to maximize the attainments of all learners.
- Reality is richer and more complex than people can fully comprehend. The goal of learning is to participate meaningfully in a cultural context rather than to attain absolute truth. Teachers are learners who are adept at facilitating growth.

These assumptions are centered on learning rather than teaching. For three decades, intensive efforts to improve teaching have had little effect on student outcomes. Looking for leverage by focussing on cognitive science's new theories about learning seems a good shift in strategy.

Assumptions About Information Technology

- The largest influence determining the current personal worldview of learners is the pervasive sensory/informational/normative context created by television, radio, videogames, movies and videotapes. By creating artificial realities that mediate people's contact with their physical and social environments, sophisticated information technologies are generating media that can be the source of unparalleled communication — or of distortion and propaganda. The fact that learners are continually immersed in virtual environments external to

schooling should shape the redesign of educational institutions. For example, educational technologies should take advantage of learners' familiarity with visual representations, and the curriculum should build students' skills in identifying bias and in separating fiction from reality.

- When integrated into an overall pedagogical strategy, current information technologies — computers, videoplayers, television — can significantly improve instruction. The media already offer learners access to a much broader range of content than was available to past generations. Now, inexpensive, portable multi-media devices have the potential for greater interactivity, cooperative learning, use situated in real-world contexts and communication across barriers of distance and time. Instructional microcomputers enable students to master information tools similar to those they will use as workers, support multiple learning styles and provide enriched educational environments based on user control and involvement. The roles of teachers and administrators have been made substantially easier by applications crafted to aid in every type of data management task.

- Beyond current information technologies, the advanced instructional devices listed in Appendix B offer the promise of improving learning because:
  - — Intelligent devices can create learning environments tailored to individual student needs.
  - — Educational technologies can present complex, motivating simulations and multimedia experiences otherwise unavailable to learners.
  - — Sophisticated technology can reduce teachers' involvement in training students about basic concepts and skills, freeing instructors to focus on the higher-order and human-centered aspects of education.
  - — Educational technologies can unobtrusively collect detailed information essential for the diagnosis and evaluation of individual learner performance.
  - — Technology can be a neutral medium free from biases and assumptions about individual 'learners' innate capabilities.
  - — Distance learning technologies can bridge barriers of distance and time to deliver instruction to students who have no other means of access to this knowledge.
  - — Computer-supported cooperative learning can enhance small group interaction as a pedagogical strategy.
  - — Using information technology in schools prepares students to use similar devices in societal settings.
  - — Applying technology to extend teachers' roles and to improve their working conditions and respect from society can increase both the quality of people entering the profession and the motivation of current teachers.
  - — Technology can provide the flexible and decentralized information systems necessary for an administrative infrastructure that can maximize learning in educational organizations.
  - — Empowering environments for creating learning materials (e.g., sophisticated authoring systems and advanced tools for instructional design) can speed curricular evolution.

— Computer-mediated communications can support teacher collaboration.

— Research on how to create intelligent processes in devices can enhance our knowledge of human teaching and learning.

For all these reasons, shifting to a technology-intensive paradigm for schooling provides our best opportunity to produce major gains in teaching/learning.

- Computers are capable of a kind of cognition complementary to human thought. People are flexible, creative, adept at recognizing complex patterns; computers excel at sophisticated manipulation of formulas. During the next decade, advanced information technologies will increasingly amplify people's intelligence through cognitive partnerships between users and intelligent tools. As the global market drives the evolution of the industrial workplace, this use of cognition enhancers will alter our culture's definitions of 'intelligence,' 'quality,' and 'effectiveness.' These shifts will profoundly affect the mission, curriculum, clients, methods, organization and location of schooling.
- The vital issue is not how many educational devices are in classrooms, but how relationships between students and teachers and schooling and society will alter as a result. As Isaac Asimov once said, the important thing to forecast is not the automobile, but the parking problem; not the television, but the soap opera. The two most common errors in technology assessment are overestimating the speed of diffusion of an innovation and underestimating its eventual consequences.

Assumptions About Organizational Design

- Evolutionary institutional change must be both bottom-up and top-down, both internally championed and externally mandated, both planned centrally and shaped by numerous microforces, and both intrinsically worthwhile and utilitarian.
- In the long run, institutions are more productive if every role is respected, excellence and quality are moving targets, incentives and resource allocations are determined by merit and rank has no special privileges. Teams that share responsibilities and rewards for services to the organization's stakeholders are more effective than hierarchies in which each individual is held accountable for doing a particular job.
- Institutional actors automatically and unconsciously shift their roles to reflect the current operational reward system (which may not be the formal incentive structure). Any major organizational change necessitates a prior shift in the institutional culture's real system of rewards and recognition, including the standards by which its stakeholders judge organizational accountability and excellence.
- In uncertain, turbulent societal environments (such as the late twentieth century), highly decentralized organizations are more effective in meeting their immediate goals and are better able to alter their mission in response to

contextual shifts. Providing services to a diverse clientele with changing needs requires flexible staffing structures with multiple roles, accountability based on performance, authority synonymous with responsibility and incentives for continual innovation.

- In evolving from its present state to some distant, desired goal, an institution must progress in quantum steps via stable intermediate structures. Each stage of evolution requires a critical mass of resources, creates a new organization more rewarding to its stakeholders than the previous stage and shifts the institutional infrastructure closer to the ultimate objective.
- When an institution uses information technology to become more productive, many dimensions of occupational roles shift. The organizational culture's goals, pace, pay, career opportunities, work standards, required skills, power, control over working conditions and status hierarchy all may alter. If a technology-intensive approach is to be effective, major changes in the organization's infrastructure must be made to minimize the costs to the institution's participants associated with these changes.
- Any institution whose services have their primary impact in the distant future must operate from a long-range perspective. Strategic thinking in educational organizations necessitates a planning horizon of decades rather than days.
- An institution's most important asset is the quality of its people. A major purpose of an organization's structure is the use of salaries, working conditions, collegiality and respect from society to attract and retain outstanding workers. Because the skills and intelligence a career in education requires are as demanding as those in any profession, to keep a quality workforce educational institutions must provide an occupational environment as attractive as those in the other professions.
- Educational institutions are systems: to be effective, a change in any aspect of the organization requires shifts in every aspect of the organization. Society's educational agents form a system: alterations in schooling necessitate changes in our culture's other learning environments (e.g., families, communities, media, the workplace). People are now part of a global system that is constantly changing on many different levels: we all have a stake in others' lifelong learning and must continually modify education as the world alters. In all these situations, the desired outcome of redesign is to create an evolutionary process rather than to reach some static goal.
- Because learning is as basic and important a human activity as breathing, all societal institutions have a stake in and a responsibility for facilitating learning. Schooling is society's most formal mechanism for enhancing human potential, but holding only schools responsible for what people learn is like holding only farmers responsible for what people eat. To sustain educational quality, every one who gains by having an intelligent society must participate in promoting learning and must perceive a personal benefit from each restructuring of schooling. First among equals in these stakeholders is the learner.

Appendix B: The Evolution of Instructional Technology

For at least another fifteen years, the information technologies will continue to increase in power while decreasing in cost. The table below presents a forecast of when some technological capabilities useful for learning will be available on high-end personal computers.

Functionality	**Uses**	**Forecasted Availability**
Hypermedia (nonlinear traversal of multi-media information)	Interlinking of diverse subject matter; easier conceptual exploration, training, collaboration	Now
High quality voice synthesis	Auditory natural language output	Now
Cognitive audit trails (automatic recording of user actions)	Support for finding patterns of suboptimal performance	Early 1990s
Advanced manipulatory input devices (e.g. gesture gloves with tactile feedback)	Mimetic learning which builds on real world experience	Early 1990s
Optical — disc systems with multiple read/ write and mixed-media capabilities	Support of large data and knowledge bases; very cheap secondary storage; facilitation of artificial realities	Early 1990s

Functionality	Uses	Forecasted Availability
High-bandwidth fiber-optic networks	Massive real time data exchange	Early 1990s
Synthesis of computers, telecommunications	Easy interconnection; realistic simulation	Early 1990s
Standardization of computer and telecommunications protocols	Easy connectivity, compatibility; lower costs	Mid 1990s
Sophisticated User Interface Management Systems	Easier development of instructional applications; reduced time for novices to master a program	Mid 1990s
Intelligent computational agents embedded in applications	Support for user-defined independent actions	Mid 1990s
Computer-supported cooperative work (collaborative design, collective problem solving, group decision support)	Mastery of team task performance	Mid 1990s
User-specific, limited-vocabulary voice recognition	Restricted natural language input	Mid 1990s
Information utilities (synthesis of media, databases, and communications)	Access to integrated sources of data and tools for assimilation	Mid 1990s
High-resolution color monitors with 3-D graphics	Vivid simulation of reality: easy reading of text	Late 1990s
Microworlds (limited, alternate realities with user control over rules)	Experience in applying theoretical information in practical situations	Late 1990s
Consciousness sensors (input of user biofeedback into computer)	Monitoring of mood, state of mind	Late 1990s

Functionality	Uses	Forecasted Availability
Microcomputer performance equivalent to current supercomputers	Sufficient power for simultaneous advanced functionalities	Late 1990s
Knowledge processing (contextually-linked data storage with embedded inference)	Goal-oriented, context-specific mastery of concepts and skills	Late 1990s
Intelligent tutors and coaches for restricted domains	Models of embedded expertise for greater individualization	Year 2000+
Artificial Realities (computer-maintained virtual worlds)	Intensely motivating simulation and experience	Year 2000+

The scenarios in the paper illustrate how these emerging functionalities might be used in future real-world contexts.

Appendix C: Current Misconceptions about Educational Technology

Six misconceptions have contributed to educators' delays in taking advantage of emerging technological capabilities:

1. The Misconception of Familiarity is that educators use additional computing power to make existing applications more efficient (e.g., more rapid searches through databases) rather than to implement innovative capabilities (such as storing information in virtual mental models: hypermedia).
2. The Misconception of Consolidation is that the wave of innovation in educational technology is almost over; we know now what these devices can and cannot do, and we need only to consolidate and refine our present model of usage. Just the opposite is true: much more powerful instructional tools are emerging, our current strategies are inadequate to maximize the benefit of these new approaches, and the real impact of technological change on educational institutions is just beginning.
3. The Misconception of Literacy is that, like language or mathematics, information technologies are predominantly a medium for manipulating and communicating symbols. Instead, emerging intelligent devices are potential intellectual partners, a new species with which to coexist. Our goal should not be student mastery of the mechanics of a medium — as with the '3 R's' — but rather complementary relationships between learners and intelligent technologies that are more than objects, but less than human.
4. The Misconception of Power is that students need less powerful devices than workplace users. On the contrary, the self-explicating interfaces and intelligent coaches helpful to novices require computers with more functionality than upper-end business workstations. Our installed base of instructional computers is woefully underpowered to support the next generation of educational applications.
5. The Misconception of Timing is that educators should defer preparing to use new types of applications until the hardware and software to support them

are widely available. In fact, building a curricular architecture and retraining teachers to take full advantage of emerging knowledge representations, such as hypermedia, will require years of advance development. More powerful workstations can create a new level of effectiveness in schools only if the cognitive and organizational infrastructure to support their use is in place before the machines are purchased.

6. The Misconception of Incrementalism is that effective innovation can be achieved by adding a little more technology to a classroom each year until finally every student has ample access to instructional devices. While such an approach does emphasize the equitable distribution of limited resources, it ignores the importance of beginning with the critical mass of equipment necessary for productive utilization. Too often, teachers become discouraged because inadequate amounts of technology produce little improvement in student performance, but this is a failing of the implementation strategy rather than the technology.

As with any systemic instructional approach, superficial attempts at technological innovation generate disappointing results. Current attempts to assess the potential of technology to improve education usually instead measure the consequences of poor adoption approaches. The primary barriers to innovation are not technological or economic, but psychological and political.

Restructuring and Technology: Partners in Change

Jane L David

Introduction

Schools are out of step with the times. Inside and out, schools look very much as they did a hundred years ago — the buildings, size and shape of classrooms, divisions based on age and how instruction is 'delivered.' Yet the world has changed remarkably during that period. Families, jobs, social organization and entertainment, among others, look nothing like they did at the turn of the century. From inside a school one would hardly know that visual images, rapid motion, technology and change are pervasive in the world outside.

The nation's public school system faces an enormous challenge: how to revamp and reorganize to prepare students to function productively in today's society. Creating more demanding goals for all students and providing curriculum and instruction that stimulate thinking and problem solving require a total restructuring of the education system from top to bottom. All parts of the system must change, so that students, teachers and administrators can take on and accomplish these more complex tasks. The combination of people's natural resistance to change and a system with limited resources make the challenge a daunting one.

Today's technology offers powerful tools for transforming what we do, what our organizations look like and even how we think about the world. Increased use of technology in schools is inevitable. As technology becomes more and more prevalent in all aspects of life, its spread will be reflected in schools. But whether significant changes in teaching and learning accompany the spread of technology in schools is an open question.

Of many imaginable scenarios for the future of technology in schools, only some affect teaching and learning directly. For example, computers will likely end up in every school's office to be used for recordkeeping and communicating with school staff and the central office. Computers may also become part of every teacher's armamentarium for their own uses (and probably bought with their own money) including recordkeeping, communicating with parents, and lesson planning. One can also imagine schools equipped with computers — as well as an array of audio, video

and telecommunication technologies — available to all teachers and students in a variety of settings for a multitude of instructional purposes. Conversely, one can all too easily imagine schools with rooms full of broken, outdated and otherwise idle equipment.

Technology clearly has the potential to vastly transform relationships between teachers and students and even what schools look like. However, the history of education reform provides scant evidence that such a transformation will occur simply because the technology exists. Schools have demonstrated an unyielding resistance to change over the decades. Reforms that are adopted tend to be those that readily fit existing organizational structures and practices (e.g., Cuban 1988).

There are two reasons to expect current and future technologies to have a different fate. First, the power, versatility, portability and ease of use of today's technology are altogether different from technologies of the past. Compare the video technology of today with instructional television (ITV) of the past, for example. A large screen monitor in the classroom, hooked directly to a multi-channel cable system, together with a VCR, laserdisk player and library of prerecorded programs, offers immediate access to a wealth of visual material, as well as total control over scheduling and sequencing. Add a camcorder, and low-cost video production becomes possible. These technologies bear little resemblance to ITV of the past, with its limited instructional software and versatility.[1]

Although these qualities of new technologies may encourage use consistent with existing practice, they will not lead to major changes in teaching and learning by themselves. The second reason — the presence of restructuring activities — is more compelling because it goes beyond technology to encompass what it takes throughout the education system to change teaching and learning.

The current nationwide movement towards restructuring the whole education system is unlike any previous educational reform in its goals, scope and support. The very language of restructuring presents a dramatically different definition of the failure of the system, and a correspondingly different view of what reform entails: the goal of fundamentally transforming teaching and learning to prepare students for the twenty-first century requires all parts of the system to change.

Moreover, the discussion extends well beyond the usual 'insiders' involved in debates over education reform. All 50 governors have made commitments to restructure the school systems in their states. Through the Business Roundtable, executives from the 200 largest corporations have made 10-year commitments to assist restructuring efforts in all 50 states. Across the country, there are superintendents, school boards, administrators, teachers and parents, as well as representatives of higher education, who acknowledge the need to restructure and have taken some first steps.

If these commitments persist and expand, technology will play a powerful role, both as a catalyst for change and as a resource that will facilitate the transformation of teaching and learning. Together, restructuring and technology become a far more powerful force for change than either alone. In the following pages, I describe what restructuring the education system means, what it takes to do it and the role technology can play. I then look briefly at current efforts to restructure and use technology and speculate about the next steps.

A Quick Overview of Restructuring[2]

Restructuring differs profoundly from previous approaches to education reform in two ways. First, it is driven by challenging goals for student learning. The goal of restructuring is to transform the current education system into one able to provide students with the kinds of skills they need in the world of today and tomorrow. This means changing what schools do, not simply improving what they are already doing.

Second, restructuring takes on the whole system. In the past, reforms have tried to change what happens in classrooms without acknowledging that much of what happens is determined by rules and regulations generated and enforced by the school administration, district office, teachers' union and school board, as well as state and federal bureaucracies. Education is an interconnected system, much like an interlocking jigsaw puzzle, and it is impossible to change one piece without changing the rest of the pieces.

Restructuring builds on what has been learned from previous reforms and from research on how people learn and how organizations change; for example, the importance of schools as organizational entities, each with its unique circumstances and culture (e.g., Goodlad 1984); the failure of externally imposed programs as solutions to education problems and, conversely, the success of solutions devised by those responsible for carrying them out (e.g., Elmore & McLaughlin 1988); and the importance of active involvement in the process of learning (e.g., Bruner 1963).

The focus of previous reforms has been to mandate what procedures educators should follow; restructuring shifts the focus to the results that their actions produce. It demands a new set of operating principles for the entire system — a shift from a rule-bound, compliance-driven system to a more flexible, decentralized system able to learn, adapt and respond to continual change. Restructuring presumes the goal for the education system is not simply to catch up to the world; it needs the capacity to continue to evolve as the world continues its rapid pace of change.

The scope of restructuring goes well beyond any previous reforms by identifying the many levels and pieces of the system that must change in order to transform the learning process. Teaching and learning must embody more challenging goals. Students must be able to understand what they read, not just recite rules and definitions; to locate, retrieve and interpret information, not merely memorize a set of facts; to identify and solve problems, not simply fill out worksheets; and to work collaboratively, as well as by themselves.

Thus, curriculum and instruction must change from an emphasis on isolated facts, skills and coverage to integrated content, applications of skills and conceptual understanding. Teaching must change from dispensing information and grading right answers to creating activities that engage students' minds and present complex problems with multiple solutions.

The locus of authority to make educationally important decisions within broad goals must shift to the school site, which in turn requires new roles for faculties. For teachers and site administrators to take on these new roles and responsibilities, district and state administrators must change their roles correspondingly, from rule making and monitoring to providing resources and helping school faculties create stimulating

learning environments. Change of this magnitude requires new roles for parents, community members, the business community and local and state policymakers, as well.

Authority carries with it responsibility for outcomes. This means that accountability must shift from the current arrangement that places authority at the top and holds people at the bottom accountable, to one that places both at the same level. It must shift from looking at procedures and narrow outcomes to focusing on results that reflect valued learning goals. Such a shift requires development of new kinds of assessment instruments that measure the kinds of thinking and problem solving skills that are the desired outcomes.

At the same time, the systems that surround elementary and secondary education must change. For example, how higher education institutions define admission criteria constrains the extent to which high schools can change. The ways in which colleges and universities prepare teachers and administrators exert tremendous influence on the ability of the elementary and secondary system to change. Similarly, how schools are accredited and staff certified and licensed, as well as how tests and textbooks are adopted, profoundly affects what happens in schools.

What It Takes to Restructure

Describing WHAT must change is different — and easier — than describing HOW it can change. Above all, restructuring asks individuals at all levels of the education system to change how they think about and do their jobs.

Imagine a typical school, divided into a number of roughly identical classrooms. Inside each classroom, the number of students, how they were assigned to the class, the content to be 'covered,' the textbook, the length of the class period, how often it meets, how success is judged (testing), not to mention the furniture, size and shape of the room and so on — all these important conditions of instruction were not chosen by the classroom teacher. They were passed down through tradition and layers of the system. The teacher is probably lecturing to the class or directing paper and pencil activities, or perhaps trying to lead a discussion with 30 students. This is how the teacher was taught, through 16 or more years of schooling, and then trained to teach.

Now we ask these teachers to stop teaching students isolated facts, emphasizing rote learning, covering the material and preparing for multiple choice tests, and instead to start teaching students how to apply skills, how to understand concepts and solve problems, how to work collaboratively and how to take responsibility for learning — in other words, to prepare students with the skills they will need to function in the workforce and in society. And we ask principals to motivate and lead this transition, and district and state administrators to lead, support and assist schools as they redefine their goals, their roles and their organizational structure.

This is a very challenging and difficult task to accomplish, especially under constraints of time, money and expertise. It does not happen by fiat; it does not happen by rhetoric alone. But it is demonstrably possible. Successful attempts to restructure in the corporate world (e.g., Kanter 1983; Peters & Waterman 1982), and early stages of restructuring efforts in education, suggest certain critical ingredients for the process of transforming teaching and learning. The following conclusions draw heavily on two studies of restructuring efforts I led for the National Governors' Association (David 1989b, David et al 1990). The first included case studies of four districts beginning to restructure, and the second involved case studies of five state restructuring initiatives.

An Invitation

First people need an occasion to change — a reason for taking on something more difficult — because it is clearly harder to do something new and different than to continue doing the same thing. So the beginning steps of restructuring require leadership that invites change — where states invite districts to change and districts invite schools to change and principals invite teachers to change. The invitation is not an engraved announcement but a signal that the goals have changed. The signal is reinforced by discussions of the nature of the problem that demands new solutions, the beliefs and values that will characterize the new system, some vision of what districts and schools can become and permission to take risks and fail. (See also, Schlechty 1990).

The occasion may be a crisis created by or taken advantage of by a leader. Or it may be a grants competition or experiment. Or it might be a more radical shift in state law inviting the creation of new schools (Kolderie 1990). The invitation may also come from outside the school system, from a foundation or corporation. The important features of the invitation are that it signals that it is no longer business as usual and that there is a sincere request for and commitment to support serious change efforts.

Authority and Flexibility

Closely related to an invitation to change is a decentralization of authority to school faculties, accompanied by the flexibility (freedom from regulation) needed to create truly different structures. School faculties cannot restructure their environments without the ability to make educationally relevant decisions based on their particular circumstances. In fact, in the absence of these, an invitation cannot be taken seriously.

This is a tricky step because formal authority is a fuzzy concept in most school districts. For example, state legislatures control school budgets in many states. Many districts have not made educationally important decisions in years beyond some marginal textbook choices and curriculum elaboration. Some types of authority do not appear on their face to be educationally important but in fact are profoundly influential, such as decisions about the architectural design of new school buildings .

Moreover, if decentralization and deregulation continue to mean token site-based management — site councils with small discretionary budgets and a chance to request waivers from certain rules — change will proceed at a snail's pace at best. At worst, teachers and administrators (and parents and students) will spend endless hours debat-

ing decisions that are not educationally important and meeting burdensome reporting requirements on needs assessments, improvement plans and evaluations. (David 1989a)

Access to Knowledge

Even with formal authority and flexibility, teachers and administrators need new knowledge and skills to do things differently. This does not mean a two-hour workshop on restructuring. It means that access to new knowledge and training is built into the job. It means creating a culture in schools and districts where ongoing learning is expected for students and adults — where there is acknowledgment that rapid change and explosion of information require continuous learning on everyone's part.

Restructuring requires new roles and responsibilities for everyone in the system which, in turn, requires a massive investment in human resource development. Corporations do not successfully change the way they do business without intensive retraining and support for all employees. Neither can schools.

Time

In addition to authority and know-how, educators need time. It is not possible for teachers and administrators to change roles, to create new learning environments and to build ongoing learning into their jobs without being provided sufficient time to do so. Layering these major responsibilities on top of existing job responsibilities undercuts the seriousness of their intent. Unfortunately, somewhere along the way time translates into money, which will always be in short supply in education. Therefore, considerable creativity must go into reallocating resources in ways that free up time for educators to take on these new responsibilities.

It also takes time to change organizational structures. Districts that have tackled decentralization in the past have devoted five to ten years to the process. Restructuring requires a long term commitment which, in turn, requires a broad coalition of support, so that the commitment can persist beyond changes in administration and elected officials.

The Role of Technology

Restructuring asks teachers and administrators to tackle more complex tasks with fewer resources. The preceding discussion offers a set of essential conditions for such change: an invitation to change, authority and flexibility, access to knowledge and time. Technology cannot in itself provide any of these conditions but it can contribute in a variety of ways to each.

Technology can invite change by signaling the need for change and compelling organizational and instructional changes in classrooms. It can help reallocate and stretch resources and extend opportunities for learning for staff and students. In addition, technology can provide support for the increased variability and complexity introduced by individually tailoring learning and decentralizing authority. Below I describe some of these potential contributions for technology, based largely on my observations as part of two ongoing studies[3] of efforts to introduce technology into schools.

Inviting Change

Technology can act as a catalyst for change in several ways. To begin with, technology can provide an occasion for change — a necessary step in restructuring. A major infusion of hardware and software into a classroom or school offers an opportunity to rethink traditional practice. Of course, dropping a roomful of dedicated drill-and-practice systems into a school does not provide an occasion for major change. But there are many alternative approaches that can serve as an invitation.

The presence of technology not only provides an opportunity for change; it also symbolizes change. New technologies are one of the most visible and obvious manifestations of how the world has changed and how quickly it continues to change. This characteristic of today's technology and what it takes to become a proficient user embody and therefore implicitly communicate many of the ideas that underlie restructuring. The introduction of technology, therefore, can lead to changes in teaching and learning that are consistent with the goals of restructuring. For example:

Learning How to Learn/No Right Answers

Teachers quickly discover that the technology — hardware and software — changes too rapidly to keep pace with. Hard decisions continually have to be made about complex trade-offs on incomplete information. There is no such thing as learning all the facts or making the one right choice. In fact, learning about technology is a career-long process because the technology will continue to change.

Teachers as Colleagues and Decision Makers

The introduction of technology fosters interactions among teachers, most of whom are equally in the dark about the subject. With thousands of pieces of software available and hardware constantly changing, teachers are anxious to learn from each other and to share experiences and knowledge. A colleague's experience is by far the most trusted source of information. The cost of technology also requires joint decisions about allocating scarce resources. Should they buy one laser printer or three dot-matrix printers? What is the trade-off between access and quality? (This situation presumes that teachers have the opportunity to make such decisions.)

Problem-solving Opportunities

Besides the software and instruction used to teach problem-solving strategies per se, student use of computers provides opportunities to develop some 'authentic' problem solving skills because there are always glitches as well as procedures to be learned. Whether a bug in the software, a malfunctioning disk drive, a faulty chip or operator error, there are always problems to be solved and students become quite adept at analyzing and solving them.

New Roles and Relationships in the Classroom

New relationships between and among teachers and students result from the presence of technology. A teacher facing students seated at computers learns quickly that he/she cannot conduct business as usual. Students turn to each other for answers to questions; teachers, who may feel threatened at first, end up turning to students; no one knows everything. Suddenly, expert knowledge is spread around and the teacher

is no longer the single authority in the class. Collaboration among students, and between students and teachers, occurs naturally.

Reallocating Resources

The potential for technology to reallocate and extend existing resources is only beginning to be tapped. There are unlikely to be sufficient funds or people to staff every school with 'the best and brightest' or to support ongoing training and retraining for all educators. Increasing the effectiveness of teaching and learning will, therefore, require serious rethinking of how resources — especially staff — are allocated, an extension of the notion of creating new roles and responsibilities across the system.

Technology cannot solve these problems but it can contribute by expanding the possible range of solutions. For example, a first grade teacher videotaped herself reading a story aloud. She then played the tape for the class, freeing herself to walk around and help students follow the story in the book. Effectively, she cloned herself in the classroom. The combination of technology and reconceiving roles throughout an entire school opens a whole new realm of possibilities for creating learning environments that look nothing like the present arrangement of one teacher per 25-35 students of the same age.

Technology can also bring resources into the classroom that facilitate active, problem-based learning and access to information otherwise unavailable or prohibitive expensive. Computer simulations, telecommunications and compact disks, even in thei infancy, extend remarkably the sources of information available to students. Moreover, the technology can better reflect the world of visual images students have grown up with, and thus have more intrinsic appeal to them. Increased student motivation and decreased discipline problems are frequently cited by teachers in technology-rich classrooms, often to their surprise.

Similarly, teachers and administrators as well as parents and students can avail themselves of a variety of workshops and courses via telecommunications. Teachers no longer need rely exclusively on what is available in their district. Teachers and students can also exchange ideas and experiences through networks, greatly expanding their repertoire of experiences.

Technology can also greatly simplify management and recordkeeping for instructional and administrative purposes, freeing the time of teachers and administrators for more substantive work. Similarly, technology can enhance services, such as communication with parents, without increasing demands on time — for example, homework telephone lines for parents, and even videotapes of classroom activities shown over local cable stations to keep parents informed.

Managing Complexity

In contrast to initial expectations, technology does not simplify teaching. In fact, introducing technology into schools as currently organized vastly increases the complexity of teachers' job because it makes possible more complex — and more effective — approaches to teaching.

Lecturing to the whole class is much simpler than organizing instruction around individual and small group projects. Giving worksheets to the class is much simpler than adapting to individual learning styles. Active learning environments also increase

student movement and communication and pose organizational, planning, management and evaluation challenges to even the strongest and most innovative teachers.

Consequently, under the best of current circumstances — where teachers have the latest technology and sufficient training and support, including encouragement for experimentation — the presence of technology complicates their jobs enormously. They are not only learning how to use technology, but they are learning how to teach differently, how to relate in new ways to their students and how to take on new roles as learners, researchers and equipment technicians.

Technology provides the potential to conduct as well as manage more complex tasks in the classroom. Ultimately, when organizational changes — teams of teachers, flexible grouping and schedules, time for learning — and the larger culture of the school and district support restructuring, the potential of technology to simultaneously increase and manage complexity will be exploited.

Technology can also contribute to solving the assessment problems intrinsic to restructuring. Education is now stuck on the horns of an assessment dilemma, both for purposes of accountability and for measuring individual student progress. Restructuring focuses attention on results, yet there are no measures adequate to the task — that is, that measure challenging goals for students. One solution is to create more authentic, and hence more complex, measures of performance. But if these richer and more meaningful results cannot be communicated as readily as grade-equivalents, they will not be widely accepted. Similarly, there is growing interest in building portfolios for students that represent the quality of their work in richer and more meaningful ways than paper and pencil tests. Such personalized assessment, however, is orders of magnitude more complex than standardized tests. Moreover, such indicators of performance are far too detailed and noncomparable for college admissions offices and policymakers to use efficiently.

With appropriate conceptual and technical work as a basis, technology has the potential to synthesize and display complex quantitative and qualitative data synthesized from a variety of sources. Thus, one assessment application of technology might be a single pictorial profile of each student — perhaps a bar graph display of eight dimensions deemed important — that could be captured instantly and printed with shadows representing the same measures at previous times (or margins of error). School profiles might be presented likewise. My hunch is that the grade-equivalent will ultimately be replaced by a picture, not by another single number. The same technology will support much richer, deeper and more tailored learning experiences by, for example, presenting a menu of resources available for students based on their assessment pictures.

Restructuring and Technology in Practice

Both restructuring and technology have enormous potential to transform our education system and vastly increase what students know and can do. Signs of restructuring are already evident in a number of states and districts, as well as individual schools. (See, for example, David 1989b, and David et al. 1990.) Progress is also evident in other

parts of the system, including teacher certification, curriculum development and assessment.

Where restructuring is taken seriously, schools and districts are beginning to look different. For example, schools are organized around teams of teachers and students who may spend several years together. Courses are cross-disciplinary and project-based; students work individually and collaboratively; teachers emphasize application of skills, conceptual understanding and problem solving. Districts are beginning to decentralize authority, encouraging school faculties to create new approaches and redefining positions and roles in the central office.

These are not new or radical ideas by themselves. What is significantly different is how teachers and administrators approach and think about these changes. In sites where educators are truly tackling restructuring, their language does not reflect what I call the 'project mentality,' an almost-universal state of mind created by the last three decades of education reform. Projects are characterized by fixed time lines, budgets, requirements and limited scope. Teachers have seen hundreds of projects and, as a result, have been acculturated to expect change to come in that form and carry a set of specific requirements for them.

Instead of the project mentality, where restructuring is underway teachers talk in terms of having begun a career-long way of doing their jobs differently. They speak of the need to continue to learn and experiment throughout their careers. Both teachers and administrators no longer see their jobs as something for which they were trained in the past and will continue to do the same way for the next 30 years.[4]

Restructuring efforts bring about visible changes in teaching and learning to the extent that the requisite ingredients are present — an invitation, authority and flexibility, access to knowledge and time. Similarly, the introduction of technology actually influences teaching and learning to the extent these same ingredients for change are present. Moreover, such changes in teaching and learning echo those described above in restructuring schools: collaboration, cross-disciplinary and project based courses, emphasis on applying skills and problem solving.

Thus, for example, Apple Computer, Inc. issued an invitation to rethink teaching and learning in its ACOT(sm)[5] projects. Each project consists of a few classrooms in a school where each student has a computer at school and at home. In addition to providing 'high-intensity access' to technology and an invitation to experiment, staff from Apple headquarters have created several other conditions for restructuring. ACOT teachers have extra planning time as well as support and training from Apple ACOT staff, both on site and at Apple headquarters. Apple's emphasis on research and development (a phrase almost never heard in school districts) has created a climate that encourages and supports experimentation and risk taking. Moreover, Apple provides opportunities for professional experiences rarely available to teachers — presentations at research meetings and conferences, summer institutes at Apple and electronic communications with colleagues at the other sites.

As a result, changes are visible in the organization of ACOT classrooms and in how teaching and learning occur in them. There is much more student interaction and movement in the classes, as students work together on projects, help each other with technical difficulties in individual work and explore new hardware and software.

Although there are major differences across sites (including grade level, type of community and innovations in instruction), no ACOT classroom would be mistaken for a traditional class.

But the effects of ACOT are limited because it involves only a few classrooms in a school and is not part of a larger school and district change effort. ACOT does have some influence outside its own classrooms; however, the influences in the opposite direction — from the outside culture that generally resists risk taking and change — are far stronger. This places added stress on ACOT teachers struggling to learn new ways of doing their jobs. The ACOT experiment also raises some hard questions, beyond the scope of this paper, about the long-term effects of changing the behaviors of a small number of teachers and students in a system that does not yet support these new behaviors.

Another example of technology introduced in concert with other ingredients for change is one of several Model Technology Schools (MTS) sites in California. Through a large five-year grant, the State of California issued an invitation to integrate technology into curriculum and instruction. This particular MTS site also invests heavily in professional development, providing an array of opportunities for all the teachers in the three MTS schools to learn to use technology before using technology for instruction, as well as school-based assistance.

At the end of three years, almost all teachers in MTS schools use technology in one way or another. There is considerable variation in use from almost none to very sophisticated uses. Some teachers use technology simply to make current strategies more efficient; for example, presenting materials on a big-screen video monitor instead of a chalkboard. Other teachers have adopted markedly different kinds of instructional strategies, such as having students use a Hypercard database of habitats to prepare for a field trip. The latter are, not surprisingly, from those teachers who have tended to be innovative in the past.

ACOT and MTS also illustrate some of the trade-offs in making decisions about technology purchases and support. ACOT has the advantage of large infusions of technology and assistance with the corresponding disadvantage of a limited number of classrooms. In contrast, MTS is schoolwide, which carries significant advantages, but each classroom has correspondingly less technology. The MTS schoolwide focus and need to pool and share resources encourages group planning and decision making. For example, in the MTS junior high school teachers share a productivity center including computers and a laser printer and, with students, share a video production center. Each department makes decisions about software purchases. In addition, schoolwide efforts are far more likely than single classrooms to influence the culture of the school. On the other hand, there are only a few computers per classroom. Consequently, uses of technology have less dramatic effects on classroom organization and instruction here than in the ACOT set-up of one computer per student.

Other configurations of technology are possible that balance demands on resources with the benefits of schoolwide approaches. One is the establishment of certain schools as research and development sites or professional development centers or other similar concepts, in which the school is designated as a place for research and development.

Looking Ahead

The widespread uses of technology in both ACOT and MTS sites are a striking contrast to most district technology purchases that have little or no discernable impact on teachers or students. Decisions to purchase dedicated systems and drill and practice software, to allocate one computer per classroom or one room of computers per school and other approaches like these are not even intended to change teaching and learning. In contrast, ACOT and MTS offer teachers a voice in technology purchases and configurations, and also provide a range of development opportunities off-campus and in the classroom on using technology to support new kinds of instruction.

Like restructuring efforts that are limited to single schools, however, efforts like ACOT and MTS will transform education only to the extent that they become part of larger district and state efforts to restructure. By themselves, they are likely to share the fate of the many projects that have preceded them. ACOT's handful of classrooms and MTS's handful of schools are limited in their progress because they are not part of larger district and state restructuring efforts. Consequently, even with an invitation (from Apple Computer for ACOT and the State of California for MTS) and access to some new knowledge, the larger systems do not provide authority and flexibility and time to learn built into the daily job of teaching.

Even with considerable resources dedicated to teaching about technology, if the other pieces necessary to support significant change are absent — knowledge about new ways to teach, and the flexibility to reorganize instruction, schedules, student grouping — only a few innovative teachers will change the way they teach as a result of the technology. These are in fact the same conditions described above as requisites for restructuring: an invitation, authority and flexibility, access to knowledge and time. Thus, whether restructuring and technology will transform teaching and learning ultimately depends upon the ability of the education system or alternative systems" to meet these conditions.

This harkens back to the central feature of restructuring — it is a systemwide process. Individual classrooms and schools cannot change substantially if the other pieces of the system do not change. Thus both MTS and ACOT are ultimately limited in the effects they can have without school, district and state support.

The same limitations apply to restructuring efforts that begin on a small-scale. One example is a high school that has redesigned much of its curriculum around multi-disciplinary courses and shifted to portfolios for student records. Faculty members wrote to some 30 colleges and universities, asking if their students would be at a disadvantage coming from a school with non-traditional courses and portfolios instead of Carnegie units and grades. The answers were that test scores would be weighted more heavily because portfolios were too time-consuming to peruse. Similarly, students in technology-rich environments engage in classroom activities that emphasize thinking and problem solving, yet are ultimately judged by standardized tests that emphasize isolated facts and recall. Until there is broader agreement on curriculum goals and adequate measures, this tension between conflicting goals will persist.

Restructuring is difficult. Learning how to use technology effectively is difficult. Both require learning new ways to teach, which in turn require changing all parts of the

system. Change is impossible to launch when skills and knowledge are absent, and it is impossible to sustain when the culture doesn't support it. But difficult as change may be, it is essential to the future of our economy and our society. The absence of change no longer means standing still; it is synonymous with moving backwards.

The concepts behind restructuring the education system and the technology that can contribute are part of a new information age paradigm, not the industrial paradigm of the past. Together they reinforce a new viewpoint which magnifies their potential to change education. To the extent that restructuring and technology are twisted to fit the old paradigm, they will not affect education practice. To the extent that restructuring and technology are driven by challenging goals for students and supported by long term commitments to change and investment in human resources, they will increase the productivity of our schools, and ultimately our society.

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End Notes

[1] And this is equipment easy to use and already familiar to most teachers and students. Adding a computer extends the power and flexibility another order of magnitude, though initially more complicated to use.

[2] Many of the ideas below are based on conversations with Michael Cohen and Susan Traiman of the National Governors' Association.

[3] SRI International's evaluation of the Model Technology Schools project in the Cupertino and Fremont Union districts in California supported by the California State Department of Education (see David et al 1989) and my own study of four Apple Classrooms of Tomorrow sites supported by Apple Computer, Inc.

[4] The label of restructuring has reached faddish proportions, hence there is little connection between the use of the label and whether or not restructuring is occurring. A good litmus test to distinguish those restructuring from those doing another project is whether they describe themselves as restructurING or restructurED — as in "We will be restructured in three years."

[5] Apple Classrooms of Tomorrow (ACOT) is a research program of Apple Computer, Inc.

[6] Arguments that the system cannot restructure itself a la Kolderie (1990) and Chubb & Moe (1990) are persuasive, and proposals to establish alternative routes for creating schools have strong appeal. Over the long haul, however, whichever routes are taken, the vast majority of current and future teachers and administrators will not be able to do their jobs differently without intensive training of a kind that is not currently offered by districts or institutions of higher education.

How Structural Change Can Speed the Introduction of Technology

Ted Kolderie

Summary

The new electronic technologies have not come into education in anything like the way they have come into business, into the home or for that matter into the military. The difference is dramatic. And it is not because these technologies hold no potential for improving productivity or performance in education. They do. Almost certainly the difference has something to do with the institution of education, which is reluctant to move toward these technologies and which in fact resists when technology is offered. Efforts to overcome this resistance have not been very successful — and have not been very sophisticated. Believers in the potential of new methods and new technology have had almost no connection with the 'reform' effort that is working currently to understand and to change what it is in education that makes the institution so resistant to innovation. They have tended simply to go on explaining the benefits of the technology for students, teachers and society, trusting that in time education will do what seems to the designers, manufacturers and advocates of technology so logical and so necessary. This must not continue. The urgency of the need to improve schools, and the impending turnover of a large part of the cadre of educators in the next few years, makes it imperative now to find an effective strategy for introducing new technology and new methods widely throughout the system. This can happen only if, at last, the discussion about technology is brought together with the discussion about the organization — the 'structure' — of the education system. This project, and this paper, is an effort to suggest a way in which that connection can be made.

The Challenge

Computers, video and the digital compact disc — and the communications equipment to link these devices — have been taken up rapidly in the world outside the schools. The appeal of these electronic devices, their productivity and their declining cost has made them a part of everyday life. They form a major part of the educational experience of children outside school, as they watch television programs and play in video arcades.

But it has been difficult to get technology introduced into the school. And even where it has been introduced it has not seemed to bring about the revolutionary change its sponsors have hoped for, in teaching and learning. Something in the institution of education resists; frustrating and disappointing those with a vision of what technology could do to help kids learn. This is not new: David Cohen has reminded us that people originally thought the book would revolutionize education; individualizing instruction. Those hopes were disappointed. The book brought learning to people outside school. But inside it became an extension of the teacher talking (Cohen, 1986).

The proponents of technology know from their experience that something in the structure of the institution is causing this resistance. But neither the theorists nor the companies selling hardware and software have so far focused their efforts on finding out what this blockage is and how to remove it. Rather, they continue to think and write and to talk to educators in districts and in schools, trying to encourage demonstrations and to get sales for their equipment and programs.

Ultimately, they seem to believe, the schools will come to accept technology — because it is good, or because it is becoming so common in the rest of society, or because the country and the students need it, or because in some way it is logical and inevitable.

The effort to introduce technology has not become a part of a larger and more strategic effort to change, at the same time, the structure of the system.

This is not particularly a criticism of those interested in technology. It is true generally that people interested in improving education (those interested in better measurement of performance, for example) have seen the importance — the necessity, really — of a basic change in system-structure as a prior requirement for the success of the change they want to bring about. A few have tried to change arrangements internal to the district, or to the school. But almost everyone, almost always, has taken the larger structure of the system as 'given.'

This is what now needs to change. If we want the schools to introduce electronic technology or new learning methods and to use these to their potential to improve the higher-order learning skills of students, we will have to be strategic. We will have to find what is causing the resistance, and change that. This will mean solving the basic problem in system-structure.

This paper will try to lay out how that might be done — to explain what it is in the system that is blocking the use of technology today, and how that blockage can be removed. Some of the ideas may be unfamiliar; some may be uncomfortable. That is inescapable. If conventional ideas could work they would have worked by now. The persistence of the problem after all the conventional efforts have failed drives us to a new approach.

The Major Elements of the System

It is unconventional to have a project that attempts to pull together all the major elements in education. Far too much of the 'improvement' or 'reform' discussion looks at only one element at a time. It is good to look at them all together; and at their interrelationships.

New Learning Methods

Some people are interested mainly in new ideas about how kids learn, and should be taught. They offer proposals for changing schooling. Some of these proposals imply or require a change in structure; some do not.

The traditional model, still dominant today, is group instruction, in which kids are taught facts and skills, by a teacher. The teacher is active; the kids largely passive. The instruction is mainly verbal. The classroom is competitive. The new model now being asserted calls for experimental or problem-based learning, in which kids work individually or in small groups, with the teacher functioning essentially as the 'coach.' Instruction is varied, to fit different learning styles, and the classroom is cooperative.

New Technology

Some people are interested in technology (as the term is used in this project, what economists call 'capital'). Traditionally the equipment for learning has been the book, the pencil and the chalkboard; later film and television; now increasingly the computer and disc. Again: Some of the proposals to expand the use of these new technologies imply or require a change in structure; some do not.

As The Role of Computer Technology in Restructuring Schools (Collins, 1990) makes clear, we can do different things with this technology. Students can learn simply how to operate the machines and programs. Or they can learn how to create computer programs. Or they can learn how to use programs, treating the programs as tools. Or they can learn from programs, treating the program as the teacher. Or they can learn with the programs, treating the programs as a situation in which they are to make decisions and solve a problem.

Restructuring and Reform

Some people are interested in structure — the institutional arrangement within which people come together, with their technology and their ideas about learning, to form what we call 'school.' This is an immensely complex topic. There are different patterns of organization, different allocations of roles and responsibility and different forms of governance. Any pattern can be organized at different scales.

The structure of public education has been fairly standard and relatively unchanged since the early years of the century. It is politically governed: essentially the responsibility and creation of the state, which regulates the system, but with schools owned and operated (and teachers hired) by local units (sometimes units of general government, sometimes special districts).

It is a districted system: Schools have boundaries. Scale varies, but has been increasing. It is a bureaucratic system, something like the military: There is line and

staff, and a hierarchy of authority. Schools are administrative units of the districts. Teachers are employees of the district (now usually unionized). Families may choose where they will live, but thereafter must attend the schools of the district in which they reside. The service is free; financed partly by local taxes and partly by aid from the state. On principle, no fees are charged.

Within the school, children are usually grouped by age and move from 'grade' to 'grade' from year to year. The classroom is self-contained in the primary years; specialized beyond about the sixth grade. At the secondary level the day is divided into periods of about 50 minutes each. Students move from subject to subject, from period to period. The classroom is under the control of the teacher. The school is under the control of a (now, usually non-teaching) 'principal.'

The Relationship Among the Elements

The elements of the system are internally consistent and mutually reinforcing. In the same way that certain plants and animals and terrain and climate form a natural ecology, the learning methods and technologies and structures form a kind of 'ecology' in the institutions of education. The idea that learning is 'delivered' by the teacher fits with the technology of the textbook and worksheet. Its prevalence reflects the structure of the system in which decisions about method and the use of resources are made outside the classroom.

Because the elements (and the people) form an interconnected system, changes in any one element almost always imply or require changes in the others as well. If the secondary changes do not occur, the attempt to change the primary element may fail. The effort to change technology often fails because the methods and structure — and the people — do not change, in response.

This was essentially the finding from Marc Tucker's work for the Carnegie Corporation about the use of computers in schools: The technology was bought and physically introduced, but not used as intended.

Inside the schools administrators were faced with a dilemma. On the one hand parents were demanding that schools respond to the 'revolution' in computer technologies; on the other, the majority of the teachers were skeptical, even hostile, about the idea. School administrators chose the middle path through the dilemma. They found a way to make the computer available to the enthusiasts, while making the smallest possible demands on those teachers and students whose enthusiasm was limited (Carnegie Corporation, 1985).

Systems other than education work differently, with their elements adapting easily to changes at any point. Sports is a good example. There are periodic changes in the technology; the equipment with which the game is played. The people and the methods --- and in time the rules — adapt to these. Changes in the method (such as the T-formation in football) produce changes in personnel. Similarly, changes in people produce changes in methods -- and in rules: Witness the arrival of the 'big man' in basketball. There are also changes over time in the structure — the rules about what

the coaches and players can and cannot do. The rules are continually adjusted by the governing body of the sport to maintain or to improve the quality of the game.

People do continually try to change one or another of the various elements in education: learning methods, technology, the 'rules' of the system, the people.

Some of the efforts are private efforts: business firms and foundations write checks to superintendents to finance research, development and the demonstration of various innovations they hope will spread. They also finance private demonstrations, in the hope these will be copied by the public schools. And there is much exhorting of educators to change. These efforts are sometimes sponsored by companies selling technology. Usually, however, each effort works on one of the elements at a time. The computer companies, for obvious reasons, are wary of the controversy that would be caused by proposals for radical changes in system-structure.

Some of the efforts are public-policy efforts. These are often focused on the structure — the 'rules' — because that is mainly what public policy controls. But states do also try from time to time to change people (better training) and to demonstrate new methods or new technologies, if not to mandate their use. The state sometimes increases the funding of the system, in the hope this will cause districts to change their schools. And the state sometimes tries to mandate the district to change. It can also adjust the structure of the system in ways that will induce districts and schools to change.

The Problem of Changing the System

The difficulty with these efforts should by now be fairly obvious. Mandates are limited in their effect. There is a strong tradition of local control that treats decisions as decisions to be made by the districts. Money also has its limitations. Districts may be happy to do what the state is willing to pay for. But the state cannot easily pay for a computer for every child on top of what it is currently spending, especially when teachers press so hard and so effectively for any available funds to come to them in salary.

Making change requires getting 'consents.' For a change it wants, the state must get the district's and the teachers' consent. For a change it wants, the district must often get the state's and the teachers' (or the union's) consent. For a change they want, the teachers must get the district's consent. Change means 'getting permission.'

In many cases permission is refused because the change would be unsettling to the organization or to individuals in it. The new technology, for example (when used as it should be used) implies the teacher becoming a facilitator. So do certain of the new and different learning/teaching methods. These in turn might require the district to accept a change in its curriculum, reducing the amount of material covered (Public Services Redesign Project, 1984). These changes are deeply unsettling. Not all teachers see themselves — or know how to function — as coaches. Large schools may feel that their long course list is their 'quality' education. Most districts do not have extra money for technology and would not consider taking existing resources away from teachers.

This resistance is a problem within education as the system has traditionally been organized. The fact of this in-built resistance is not in controversy. One major study of American schools said plainly, "The cards are stacked against innovation" (Goodlad, 1984).

Education is, as noted, a political system. It is oriented to the majority, and to those most influential politically. Educators make sure schools work well for these constituencies. This is reflected in surveys that show the majority of Americans generally satisfied with their schools. The system provides middle-class suburbs with control over their own schools. The people for whom the schools work badly are a minority in each state, and are segregated locally into 'their own' districts.

It is also a labor-intensive system. Proposals (usually from management) to introduce technology are examined carefully by teachers and their organizations to make sure they do not affect teacher interests adversely. This is reflected in proposals offered (for example, in bargaining in Minnesota) that would: (a) limit the size of telecommunications classes to 13 students; (b) require the district to grant additional preparation time; (c) prohibit a district from requiring a teacher to teach a televised course; (d) require the district to offer the course on the basis of seniority; (e) prohibit a district from putting any teacher on unrequested leave of absence if he is licensed in an area in which the district is offering or receiving a course via telecommunications; and (f) require the district to provide a teacher also at the remote (receiving) site, who will be responsible only for student behavior at that site and who may not be assigned to this duty during prep time or when performing other duties (i.e., nurse, librarian, etc.).

Smaller districts in sparsely-settled areas feel a need to introduce technology (i.e., to use computerized instruction) not felt by larger districts with greater resources to hire teachers. Teacher organizations are sometimes heavily involved in pressing states to enlarge the scale of district organization — to consolidate small districts into larger ones, to provide a stronger tax base better able to afford teacher salaries. The effect if not the intention is to remove a pressure for the use of technology.

But the most important resistance comes out of the basic structural arrangements in the system.

The schools are under the control of districts. The district makes decisions about learning/teaching methods and technology. It controls the people, the curriculum and learning program, and the money to introduce technology on a widespread scale. The states do not make decisions about technology. Nor do the schools. The districts do. Typically districts spend their available funds to enrich the existing teacher-oriented learning methodology and the teaching-oriented technology. This is rational under existing arrangements.

The district could change its schools — change its technology — but has no reason to do so. Customers are required by law to use its services. Costs are fully covered by tax revenues; appropriated to the district by local voters or by the state. And the boundaries in the system provide the district with an 'exclusive' that relieves it of the need to change.

It is the perverse incentives created by the districting of the system that 'stack the cards' against innovation. In plain words, the structure of the system creates a situation in which -- because the district can take its students for granted -- change becomes unnecessary.

Persons interested in technology need to see clearly the full implications of the current system-incentives: change is unnecessary even where it would improve the education of the students. The existing structural arrangements mean that for the districts practically nothing depends on whether students learn. These arrangements guarantee the district, and the people in it, their continued existence, their students, their revenues, their jobs, their security — most of their material success — independent of the level of student success.

Proposals — including proposals to use technology — that might increase student success are therefore evaluated in the system very largely in terms of the other effects they might have — in plain words, in terms of the degree to which they might 'upset' existing, comfortable arrangements. This is reflected in the common observation of teachers and others in education that pushing for change is hard — that change is a risk. And, as George Young noted in an article about the problem of introducing computer technology, when a superintendent in Saint Paul, Minnesota: "Institutions have lives of their own. They resist change. Change is a threat. They have strategies for resisting change. If those strategies do not work, and change is introduced, they have other strategies to neutralize the change" (Young, 1981).

None of this is a criticism of the people in education; many of whom accept lower rewards, poorer working conditions and a more difficult assignment than employees in other fields because of their commitment to children. It is a criticism of the system in which they have been placed, which presents them with a structure of incentives — of opportunity and reward — that imposes the risks on those who do try to improve and that supports those who do not.

This analysis has been laid out more fully elsewhere (Kolderie, 1990). Its implications for policy are resisted by persons in public education, but the analysis itself is not basically disputed. From any of several standpoints — the need to improve student learning, the need to rescue children in inner cities, the need to realize the potential of technology — the present system is a bad system. Its incentives are not aligned either with the interests of the nation or with the needs of the students.

A Strategy for Encouraging Innovation

There needs to be a new strategy for introducing and expanding technology in education. Simply explaining to educators the potential of new technologies and new learning methods will not be enough. Simply marketing these ideas to superintendents and curriculum directors will not be enough. Simply exhorting people to do what they have no reason to do will not be enough.

Results are not zero: There are demonstrations, and some adoptions. But the results are not adequate. Worse: even where introduced the technology is not used as it should be used. In some cases districts that buy a computer-reading program use it as a supplement, while they continue also to teach reading in the traditional way. And some computer technology is marketed to teachers not to individualize instruction or to make the students more active, but explicitly on the assurance that it will permit teachers to maintain (and to enhance) their traditional control of full group instruction.

Clearly, the condition necessary for the widespread use of new technology and new learning methods is a prior change in the basic structure of the system of education, which will introduce both incentives and opportunities for the people in the system to welcome these changes, in their own interest.

Several efforts have been made, or proposed, in recent years to 'restructure' education.

The best-known is the effort at school-site (or school-based) management. The idea builds off the research that concludes that the school should be the unit of improvement. The board and superintendent would delegate to the school the authority to make the instructional decisions, give the school its resources (money, people, time, etc.) as a block and hold the school accountable in terms of student performance. It is an appealing idea, has been aggressively promoted, and is commonly recommended by committees — and journalists — as a way to improve performance, and to encourage innovation.

The performance is not, however, up to the promise. Many boards do not want to make a real delegation of meaningful authority to the school. Some schools do not want to accept such a delegation. Teachers are often unenthusiastic about taking on what they see as management roles. Parents, principals and teachers are often in conflict over who would control whatever authority would come to the school. In practice not much gets delegated. And there is not a lot of evidence that even what does is used to change what happens in the classroom. Arguably it is a debate among adults, about control (Kolderie, 1988).

In its conventional form the site-management idea does not change the fundamentals. It provides little opportunity for change; and less incentive. The cards are still stacked against innovation.

The critical change that is needed in structure is not within the district or within the school. The critical change that is needed is in the state system, beyond the district.

This is a radically non-traditional view of the problem in education, and one not much shared by persons long in the system and comfortable in the institution. But it should be apparent quickly to persons interested in changing education that their interest is precisely in actions — even if radical — that will enlarge the system-capacity for change.

More than this: they should see too that the prospect for new technology and new learning methods would be greatly increased if it were possible not simply to reform existing schools but also to create new different and better public schools. New schools would create a market for new technologies and new approaches, while at the same time stimulating the existing schools to introduce the same innovations themselves.

The 'state system' can be changed only by the state. Currently, only the local board can start a public school; and the local board is unlikely to go into competition with itself. The state would have to act to make it possible for some other public body to offer public school on the same piece of ground.

Such an action is within the authority of the states, and has in fact been suggested to governors as an action they might take to implement the national goals for education (National Governors' Association, 1990).

Two actions are needed. The first is to make it possible for new public schools to appear, which students can choose. The second is to make it possible for teachers to own the schools.

New Public Schools

The conclusion from research that the individual school should increasingly be the unit of improvement has been given a substantial boost since about 1987 by the growing policy advocacy for school choice; most recently, by the book arguing for a general system of a 'autonomous' schools (Chubb and Moe, 1990). This is closely associated, however, with the effort to make non-public schools eligible for public funding. That strategy uses existing schools as alternative schools. It does not, as a result, provide an opportunity to start schools new.

To provide the opportunity to design and build new and different schools 'from the ground up' the state will need to authorize public bodies other than the local school district to start, or sponsor (i.e., contract with) schools. The local district is unlikely to start innovative schools that would compete with the schools it presently owns.

The 'other body' might be a local school district, opening a school in the territory of another. Or it might be a college or university, as an extension of its educational-research or teacher-education program. Or the state itself.

The state would of course at the same time make these new schools 'schools of choice' for students.

The issues involved in implementing such a strategy would have been dealt with elsewhere. The mechanics of how it would work are important, but not central. There are several possible answers to each of the major questions; and different states can appropriately come to different decisions. What is central is the need for such a strategy — for the state to remove what has suppressed technological and other innovation, by withdrawing from districts the assurance that they can take their students for granted (Kolderie, 1990).

Schools Owned by Their Teachers

The new learning-organization — whether literally a whole school, a group of schools or parts of a school (a department, a program or a grade level) — would be an independent entity. Such an organization could take any one of several forms, under the laws of most states. The way should be open for the new learning-organization to be formed and owned by educators and by teachers. This is important to create the incentives for the introduction of new learning methods and new technology.

Teachers' influence is critical on decisions about introducing — and especially about using — new technology and new methods. Little incentive exists today for them to change the instructional process in their classrooms: used to its potential, the new technology implies a major change in the role of the teacher. There may be a fear that 'the machine will become the teacher.' Teachers were trained to feel that kids learn from them. They hear the argument that they will feel rewarded when kids do better ('psychic payoff'). And many teachers do respond positively to this: professional pride is real. But as a public strategy this essentially exploits their altruism. It provides teachers with little tangible reward.

And no opportunity. Even if persuaded by the potential of new technology teachers have little ability to act. Under present arrangements decisions about technology are in the hands of management; requiring an authority and a control over resources which the teachers do not possess.

And in all, it is entirely understandable that teachers take little initiative to seek new methods and new technology.

This situation derives, however, from the traditional structure of education, which requires a teacher to be an employee. There is no inherent reason why teachers must be employed: in most service and information fields people have at least the option to work in a professional way, for themselves; alone or with partners in groups. But it has been traditional in education, in private schools as well as in public, that if you want to be a teacher you have to be an employee.

The challenge for those interested in new methods and new technologies is to tap the potential for innovation and for productivity present in the idea of reuniting ownership and work. A provocative article by Max Geldens and Norman Macrae offers an important perspective on this question of incentive (Economist, 1984) and makes clear the important implications.

They begin with a simple model of the evolution of the economy: from farmer to worker to clerk.

When most people worked in agriculture, they note, the worker and the owner were one and the same. So new methods and new technologies that made work both easier and more profitable were taken up quickly. Agriculture was modernized. Productivity rose dramatically. Farmers became fewer but enormously better off. And society was better off.

In the industrial era scale enlarged, and ownership and work came to be separated. Steel mills and railroads and automobile factories came to be owned by organizations of capital. The workers became employees. New technology that improved productivity provided benefits to the owners. To protect their jobs the workers initially 'went Luddite,' resisting new technology. When this failed they organized to fight with employers for a share of the gains from technology. In this situation and out of this experience workers in many fields remain skeptical today about new technology.

The question is: which of these two previous stages is the information/services economy more like?

Inherently the service and information activity would seem to be like farming: The capital requirements are very low, and the workers could clearly be the owners. In many sectors the new information workers do in fact work for themselves: lawyers, doctors, accountants, engineers, architects and especially people in the arts and communications.

Education is the conspicuous exception: a system organized classically on the industrial-era model with large organizations (Chicago has almost 600 schools; New York City almost 1,000) in which ownership and work are separated. The workers are employees, trapped in many cases in what are essentially dead-end jobs. They are skeptical of new technology. And there is no equivalent, in this public and political system, of the imported automobile.

It is hard to feel that education could not also be arranged as a system in which, because the workers are the owners, productivity improvements are encouraged. That — again — is the strategic change in system-structure needed to encourage the spread of new learning methods and new learning technology.

A major part of the current push for 'restructuring' education involves upgrading teachers to true professional status. The test of a professional, however, is to control his own work — to be able to say, "tell me what you want done; Don't tell me how to do it. I know how to do it."

A group of teachers might own a whole school; or a group of schools or a part of a school. They would be capitated with a per-pupil amount, allowed to make decisions on technology and on the method of instruction, and would be able to keep — either for use in the program or as a personal income — what they did not need to spend. The incentive for them would be to move toward changes that would improve student learning, that would not require them to spend money they could otherwise keep. As teachers themselves say, this means: toward individualized study, toward parent involvement, toward differentiated staffing, toward new learning methods and (though this is not cost-less) toward technology (Kolderie, 1982).

It will puzzle and frustrate many of the organizations in the field of learning technology — certainly the companies selling computer hardware and software — to be told that the market must first be restructured in ways that will involve them selling to teachers. That may be, however, what is implied. It will not be easy. But it can be done — probably by working through a new organization which they do not control directly.

The Urgency of This Change

Everyone interested in expanding the use of new learning methods and new technologies in education should think through the implications of the prospective resignation and retirement of a large proportion of the teacher and administrative cadre during the 1990s.

This turnover appears to be real (Darling-Hammond, 1984). The concern is that it will not be possible to find a million quality replacements; and that as a result the competence of the system will fall — worst in the cities that need improvement the most.

Note that this concern is commonly phrased in terms that assume the traditional methods of teaching: the talk is in terms of 'finding people.' Those involved debate whether there will be enough or not, of the right quality or not, and whether we can in time train or retrain the 'replacements.' It is almost entirely conventional thinking, which assumes that education will continue to be and must necessarily be a labor-intensive activity.

It is not clear that the persons and the organizations interested in new methods and new technologies have become effectively involved in this question about the

teacher supply — inherently a question about the system of instruction for the future — any more than they have been involved in the debate over system-structure.

They should be. The prospect is bleak that, on a national basis and especially in the cities, enough quality recruits can be found. It would almost be worse if they could be found: The reserve pool would supply teachers trained in traditional methods and the teacher-training institutions cannot conceivably be reoriented in time. Alternative paths into teaching can open up only slowly. If the system is simply 're-staffed' with traditional people the opportunity to introduce new technologies may be effectively foreclosed for another generation.

The great opportunity is to reset the definition of 'the coming crisis in teaching' — to get people to see this turnover of the cadre as an opportunity to break with the old labor-intensive concept of schooling by making it in the interest of the teachers themselves to shift the 'mix' of labor and capital in the system as the turnover in staff occurs.

In Conclusion

Efforts to change and to improve learning methods and technologies in education will not succeed if they rely on missionaries preaching the potential of the 'black box,' and on attempts to persuade administrators to do things they find personally difficult and institutionally unnecessary, simply because these are important for the country and good for kids.

The effort must become strategic. The people and the organizations involved in the effort need to operate from an understanding that the present structure of education presents absolutely fundamental obstacles to the change they are trying to bring about. Nothing in the system now makes improved technology or learning methods necessary. The strategy must be to restructure education in ways that will make improvement necessary, so that districts and schools will move affirmatively toward innovations, in their own interest and from their own resources.

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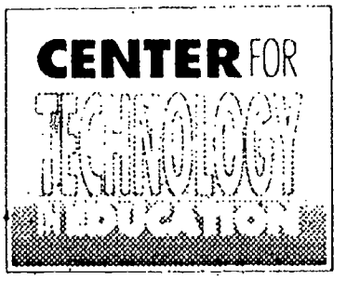

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